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SURVIVAL DURING THE FIRST YEAR AFTER A NUCLEAR ATTACK.(U)
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SURVIVAL DURING THE FIRST YEAR AFTER A NUCLEAR ATTACK

FINAL REPORT
SPC 488

See 1473

December 1979

by
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for
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Washington, D.C. 20472
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CONTENTS

I. EXECUTIVE SUMMARY

A. PURPOSE

The purpose of the present study is to analyze the extent to which survivors of the initial blast and fallout from a large-scale nuclear attack against the United States could continue to survive during the first year afterwards. Earlier studies of the overall environment following a large-scale nuclear attack have generally dealt either with the first few weeks after the attack, during which many people would have to stay in fallout shelters, or with recovery over a period of several years following the attack, beginning with the end of the first year. The present study is an attempt to fill the gap between these two types of earlier studies.

This effort was performed by System Planning Corporation for the Federal Emergency Management Agency (FEMA).

B. APPROACH

Since it was not possible in this limited study to analyze the U.S. as a whole in the level of detail desired, an individual state was selected for detailed analysis. Ohio was chosen as the best "index state" for the U.S. as a whole. For simplicity, Ohio was assumed to be isolated during the first year.

It was assumed that the U.S. had adopted the full crisis relocation program that was recommended by the Secretary of Defense in 1978, sometimes known as Program D-Prime. During a crisis prior to the attack, the people were assumed to have relocated and to have established expedient fallout protection in the rural host areas. It was assumed that detailed Emergency Public Information regarding life after an attack had been provided to the people, and that plans for postattack allocation had been

made, but that neither stockpiling nor crisis relocation of key materials had been carried out.

A single large-scale nuclear attack was assumed to be directed against U.S. military and industrial targets and cities of population greater than 50,000. Evacuees were not targeted. About 80 percent of the yield was surface-burst, thus producing extensive fallout.

Only tangible quantities directly relevant to life and health were considered. Such organizational necessities as government and economy were assumed to be sufficiently effective to preserve some order and to provide a reasonable distribution of available goods and services.

For each of the 88 Ohio counties, calculations were made of the levels of blast and fallout and the numbers of fatalities and injuries among the relocated population. Then, for the initial survivors, the question of continued survival was analyzed with respect to the following factors: energy, transportation, food, water, housing, clothing, sanitation, health, communications, emergency services, residual radiation, and environmental effects. For each of these, previous studies were reviewed, relevant data for Ohio were obtained, and the effect on the initial survivors was examined.

C. FINDINGS

If no protective action were taken by the people, only about 20 percent would survive the initial blast and fallout. However, if Program D-Prime were adopted, and successfully implemented prior to the postulated attack, then approximately 80 percent of the population of Ohio would survive. This finding (hand-calculated) is an independent confirmation of similar results obtained using large computer codes to study the effects for the U.S. as a whole.

Life after such an attack would be considerably more primitive and difficult then it is in the U.S. today. However, the only serious threat to overall continued survival might be lack of food, and whether or not

this would be a problem would depend on the attack season and other details. This uncertainty could be removed by stockpiling grain.

For each specific factor, the findings were as follows:

- Energy: Coal production facilities would survive. Several coal-burning electric power plants would survive. Petroleum refinery capability would be destroyed. Surviving petroleum fuel would probably be adequate for transportation of essential goods and other emergency functions, but possibly not for full mechanized farming, and definitely not for use of private automobiles.
- Transportation: Most cars, trucks, and trains, plus an extensive network of roads and tracks, would survive.
- Food: Most farm animals would be killed by fallout. People would have to shift to a much more grain-oriented diet. Whether surviving stored food would be adequate to feed the surviving population for a year would depend on the season of the attack. The next crop following the attack could probably be mostly saved, although it might be destroyed by heavy fallout and/or bad weather during the in-shelter period. Effects of these uncertainties could be removed by stockpiling grain in rural areas.
- Water: Postattack water supplies would apparently be adequate.
- Housing: Until rebuilding occurred, people would have to live at 2 to 4 times current densities, but this is still feasible.
- Clothing: Preattack clothing would largely survive and could be used for several years after the attack.
- Sanitation: Waste disposal would be primitive for some sections of population, but again, this is feasible.
- Health: Fatalities from disease would increase, possibly by an order of magnitude over the normal peacetime rate, but not to levels comparable to the fatalities from the initial blast and fallout.
- Communications: Many radio and TV stations would survive. A small fraction of total surviving fuel supplies could power them for well over a year.
- Emergency Services: Surviving emergency officials and vehicles per capita would be comparable to preattack levels.
- Residual Radiation: Late fatalities from residual radiation would be a few percent, or less, of the people surviving the initial blast and fallout.

- <u>Environmental Effects</u>: Depletion of the ozone layer, and consequent increase in ultraviolet radiation, might occur. However, severe damage to people would be unlikely. Staple crops (especially corn) would probably not be significantly damaged. Other significant environmental effects appear unlikely.

For each factor considered (water, health, etc.), preattack preparations would reduce uncertainties and prevent fatalities in the postattack environment.

D. RECOMMENDATIONS

This study has suggested many preventive measures, which, if employed in peacetime, could significantly improve the situation of the survivors during the first postattack year. The more important measures are the following:

- Identify key materials for survival during the postattack period, such as food, fuel, agricultural necessities (seed, fertilizer, insecticides, pesticides), sleeping bags, medicines (preventive and curative), bicycles, batteries, and substances for countering radioactive food contamination and increased ultraviolet radiation.
    - -- Plan/prepare for relocating such items from risk to non-risk areas if crisis relocation is enacted
    - -- Plan/prepare for producing and distributing extra amounts of such items (especially consumables) if a prolonged period of international tension occurs
    - -- Stockpile such items (especially consumables) in peacetime, in non-risk areas.
- Provide crisis instructions to the public regarding a postattack environment: how to live in the host area for an extended period if an attack occurs and one's home is destroyed. Include instructions for manual agricultural, and for the conversion of raw grain into edible food.
- Advise evacuees to take with them key items that they own--not only food, medicines, portable radios, and batteries, but also gardening supplies, sleeping bags, warm clothing (regardless of season of attack), and bicyles.
- Plan/prepare for relocating trucks, buses, railroad rolling stock, aircraft, and possibly boats, from risk to non-risk areas, during a crisis period.

- Plan/prepare for manual pumping of fuel stored underground.
- Plan/prepare for manual pumping of groundwater from wells.
- Plan/prepare for diagnosis of communicable diseases and possible immunization against their effects.

II. BASIC ASSUMPTIONS

A. SURVIVAL AND RECOVERY

A large-scale nuclear attack against military and economic targets in the United States would result in great damage to the population, the economy, the political infrastructure, and the natural environment. To speak of national "recovery" from such an attack is to imply the regaining of a certain preattack position or condition by the United States. Given the extensive damage likely in the wake of a large-scale attack, recovery would necessarily be a complex process.

Because of this, recovery can be conceptualized as occurring in phases. Former RAND economist Sidney G. Winter, Jr. has partitioned the postattack recovery period into three phases: survival, reorganization, and recuperation [Refs. 1-3]. A number of analyses have assumed that the period divided into the survival and reorganization phases by Winter would last roughly a year [Refs. 4-8].

The present study is concerned solely with the first year after the attack; i.e., with Winter's first two phases. Furthermore, it is concerned only with matters directly relevant to life and health.

B. SELECTION OF OHIO FOR DETAILED ANALYSIS

Analysis of the U.S. as a whole, at the level of detail desired, would not have been possible within the limited resources of the study. Therefore, it was decided to choose a region of the U.S. that would be typical and could serve as a good index for the nation. An individual city or county would have been too small, since it was necessary to choose a region containing both urban and rural areas, within which people would

be assumed to relocate during the crisis period prior to the attack. Because relocation plans are currently being made on a state basis, it was decided that a specific state would be selected for the detailed analysis.

To make the analysis tractable, it was assumed that the state chosen would be completely isolated (no interstate transportation) for the first year after the attack, thus assuming a somewhat worse-than-likely case in this respect.

Several criteria were chosen for selecting a specific state: (1) the state should not be unusually far north or south; (2) the ratio of population of arable land in the state should be similar to that ratio for the nation as a whole (the second criterion should be a major determinant of the state selected because of the critical importance of available food supplies during the first year); (3) the state's population distribution (as measured by the relative sizes of the urban and rural populations and also by the population density) should be similar to, if not "worse" (i.e., more urban, more dense) than the population distribution for the entire country; (4) the state's industrial/agricultural mix (as measured by the percentages of nonfarm and farm personal income) should be close to that for the nation as a whole.

As a result of this initial process of elimination, a band of states--Illinois, Indiana, Michigan, Ohio, and Pennsylvania--remained for further scrutiny. These six states were compared in terms of the four criteria. The relevant data are summarized in Table 1.

Overall, Ohio appeared to be the best state of the set to select for a detailed study. The state has a cold winter as well as a varied climate. The division of its population between urban and rural areas is almost identical to that of the nation as a whole (approximately three-quarters of the population urban and one-quarter rural). The harvested acreage per person in Ohio is 1.02, versus 1.52 for the United States (making Ohio a somewhat worse than average case for the purposes of this analysis).

TABLE 1. BASIS FOR SELECTING OHIO

State	Population		Population Density (people/mi^2)	Harvested Acre Per Person	Personal Income	
	Percent Urban	Percent Rural			Percent Non-Farm	Percent Farm
Illinois	83	17	201.4	2.06	98	2
Indiana	65	35	146.9	2.38	96	4
Michigan	74	26	160.2	0.70	99	1
Ohio	75	25	260.9	1.02	98	2
Pennsylvania	71	29	263.8	0.38	99	1
United States	73	27	60.7	1.52	98	2

Finally, the proportions of non-farm and farm income are the same as those for the whole country. Figure 1 summarizes some basic aspects of Ohio's political geography.

C. CIVIL DEFENSE

It is assumed for this study that the U.S. has adopted and implemented the Crisis Relocation Program (CRP) recommended by the Secretary of Defense, sometimes known as "Program D-Prime," which includes increased emphasis on Emergency Public Information, Radiological Defense, Emergency Operating Centers, warning systems, shelter survey and stocking, training of shelter managers, and overall planning [Refs. 9, 10]. It is further assumed that an intense crisis occurs, and, following the instructions of officials, most people relocate from urban and other high-risk areas to lower-risk rural areas, called "host areas." In host areas, evacuees would upgrade the fallout protection capability of existing public buildings as much as possible by piling earth around the sides and in some cases on top. The details of relocation have all been studied [Ref. 11]. An earlier study concluded that such a relocation, were it ever ordered by the President in an intense crisis, could be accomplished successfully within a few days, and that most people would probably cooperate by enduring the discomforts of living in the expedient shelter space for the required time (a few days to a month) [Ref. 9]. Based on previous analyses, it is assumed that the overall equivalent fallout protection factor (PF)[1] of the relocated population is 50 [Refs. 9, 10], although field tests have shown that PFs of a few hundred are entirely possible [Ref. 12; see also Table 2]. Actual PFs would vary. Moreover, exposure control countermeasures (e.g., decontamination) could further reduce postattack radiation exposure.

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[1]If a person is in a shelter with a certain fallout protection factor (PF), then the radiation dose that he receives is equal to 1/PF times the dose that he would receive if he were standing in the middle of a large, flat field. Thus, the higher the PF, the better the fallout protection.

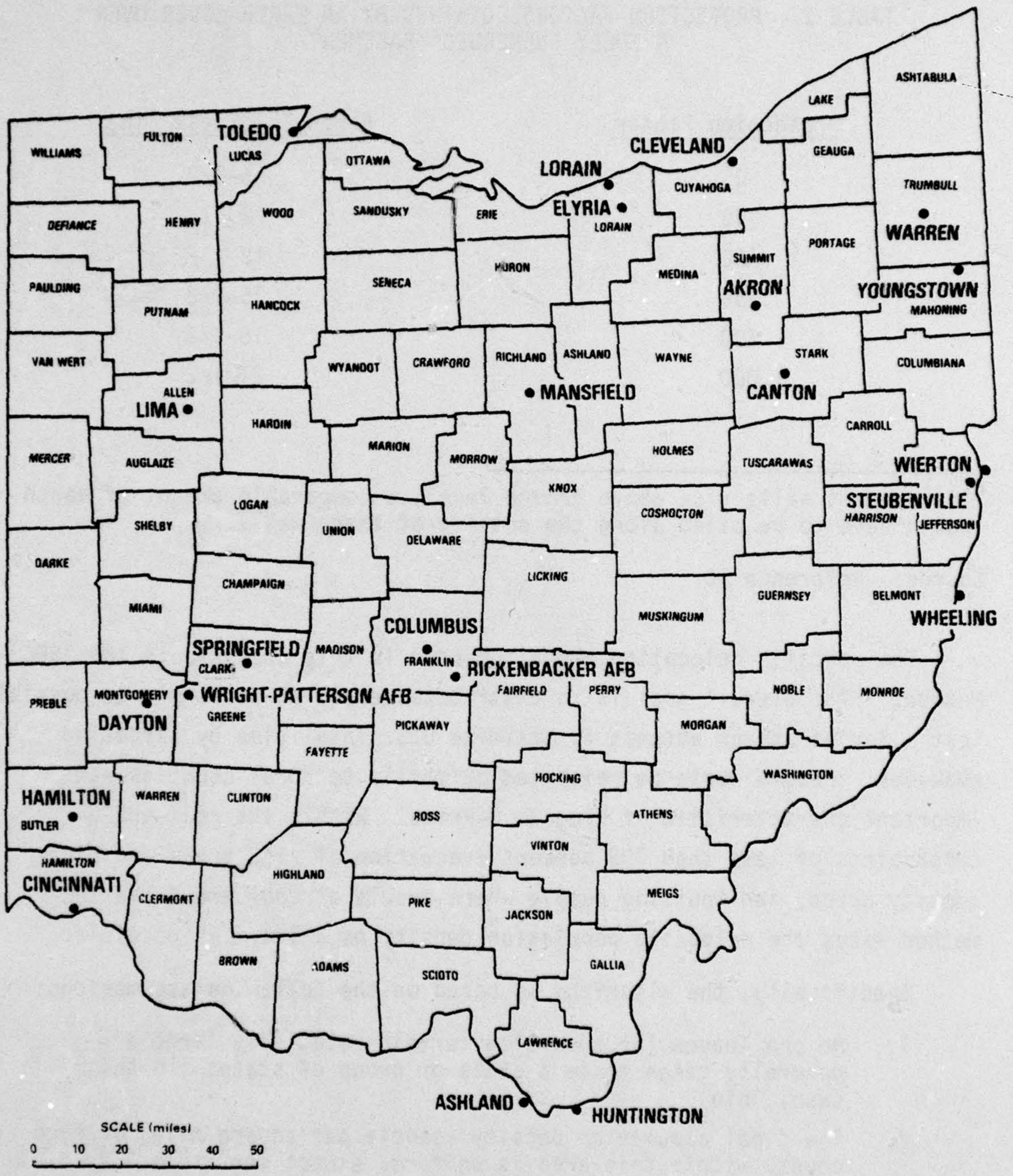


FIGURE 1. OHIO CITIES AND AIR FORCE BASES AND CITIES IN ADJACENT STATES

TABLE 2. PROTECTION FACTORS OBTAINED BY AN EARTH COVER OVER A FULLY SUBMERGED[a] BASEMENT

Protection Factor	Earth Thickness (in)
25	6-1/2
50	9
100	12
250	15-1/2
500	18-1/2
1,000	21-1/2

[a]If basement walls rise above ground level, a comparable amount of earth would have to be piled along the outside of these walls.

Source: Reference 10.

The specific relocation algorithm used in this analysis is the "SPC Method." The overall goal is to distribute people as uniformly as possible, lest a Soviet attack attempt to maximize U.S. fatalities by targeting evacuees. People would be relocated primarily to rural counties--an important characteristic of Program D-Prime. Within the real-world constraints of less than 100 percent evacuation of risk areas and high-density areas, and "putting people where people already are," the SPC method makes the relocated population density as uniform as possible.

Specifically, the algorithm is based on the following assumptions:

1. No one leaves (or enters) a certain relatively large area, generally taken to be a state or group of states (in this case, Ohio).
2. The final population density (people per square mile) of each county within this area is uniform, except for items 3 to 6 below.
3. No county has a final-to-initial (F/I) population ratio greater than some specified value H (H = 6.0 was chosen, per Ref. 13). This ensures "putting people where people already are."

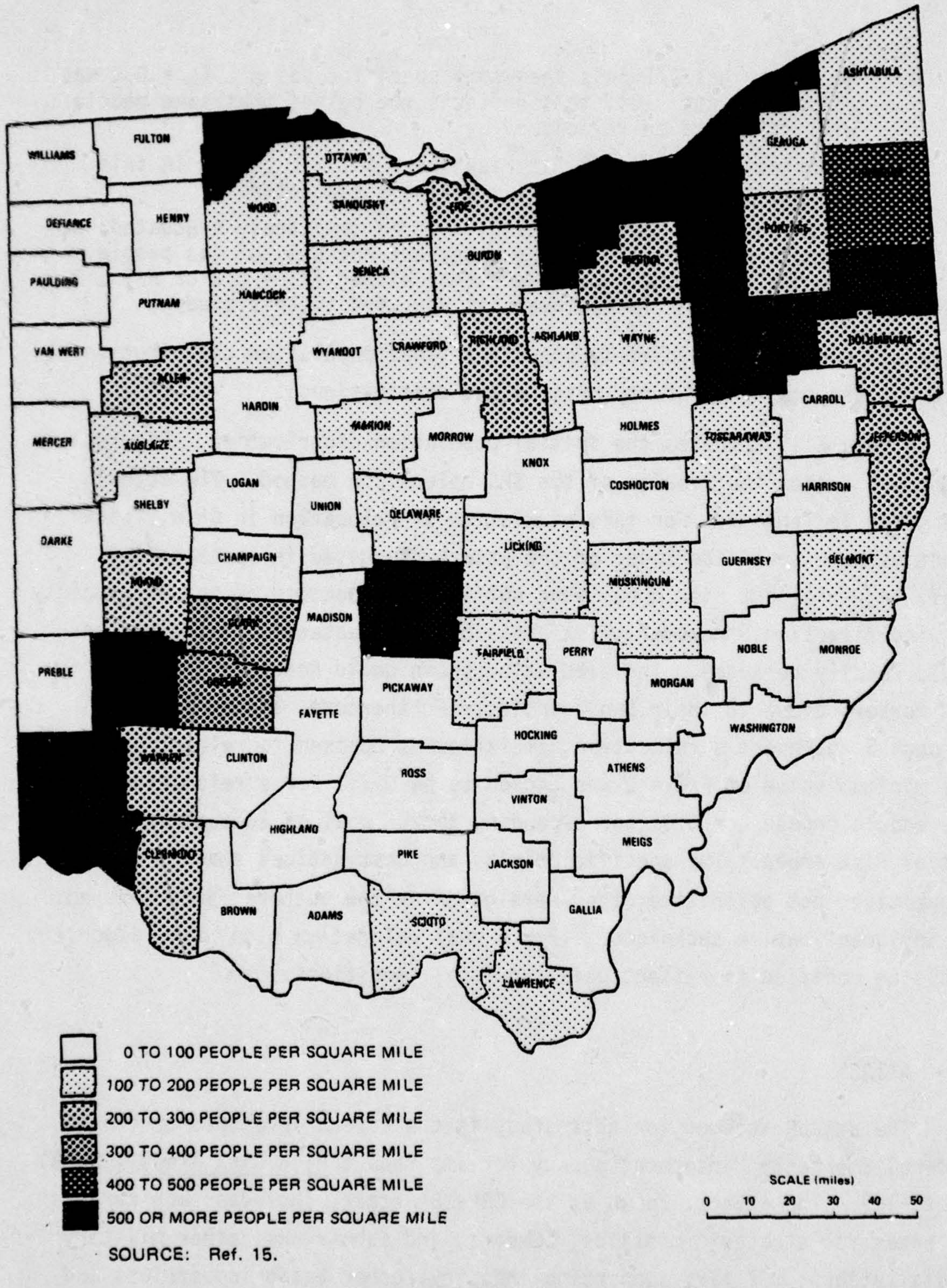
4. No county has F/I less than some specified value L (L = 0.2 was chosen per Ref. 13); this reflects the belief that some people will refuse to be relocated.
5. Counties designated as "at risk" have F/I = L (= 0.2 in this study); i.e., risk counties are always evacuated.
6. If a county is evacuated at all, it is completely evacuated; no county is asked to evacuate some, but not all, of its people. For the algorithm, this means that either F/I = 0.2 or F/I ≥ 1.0. (This condition is optional; it was used in this study.)

These six conditions completely specify a final population distribution (but not the county-by-county origins and destinations).

Figure 2 illustrates the initial population distribution. Figures 3 through 5 show the results of the SPC relocation method. The details are given in Table 3. For this simulation of relocation in Ohio, "risk" counties were specified based on the attack discussed in Section II-D [Ref. 14]. Fallout risk areas were not included because of the uncertainty of wind direction. However, risk areas based on potential fallout dose could readily be added. The simulation shown would keep the community key workers close to their own counties. Furthermore, since Figures 3 through 5 represent a relocation simulation as opposed to relocation plan, the minimum value of F/I = L was chosen to be 0.2. For a relocation plan, one should choose L = 0.0, corresponding to the goal of evacuating everyone out of risk areas. The specific origins and destinations shown are suggestive, not definitive; they were based on the authors' judgment, not on any quantitative technique. (For a real relocation plan, this algorithm would be modified to reflect detailed local conditions.)

D. ATTACK

Th[illegible]ttack assumed for this study is the attack developed by the Federal Emergency Management Agency for its report High Risk Areas (TR-82) [Ref. 14]. The attack, known as the CRP-2B Attack, includes such targets as bases for strategic missiles, bombers, and submarines; other military installations; military supporting industry; other basic industries; and urban population centers of more than 50,000 people. A map of the blast



SOURCE: Ref. 15.

FIGURE 2. INITIAL POPULATION DENSITY OF OHIO (Total Population = 10.7 MILLION)

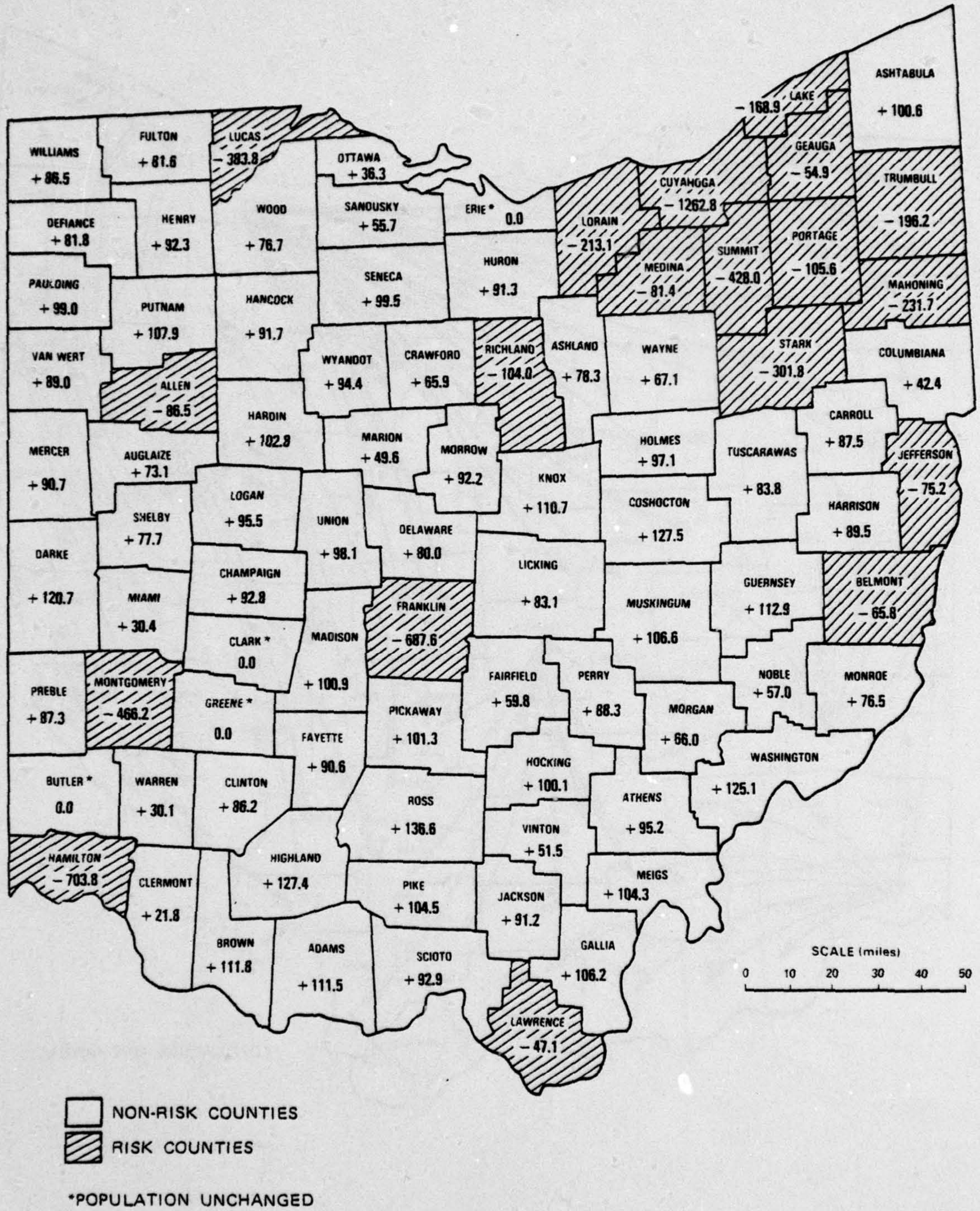


FIGURE 3. RELOCATION CHANGES IN COUNTY POPULATIONS IN OHIO, SPC METHOD

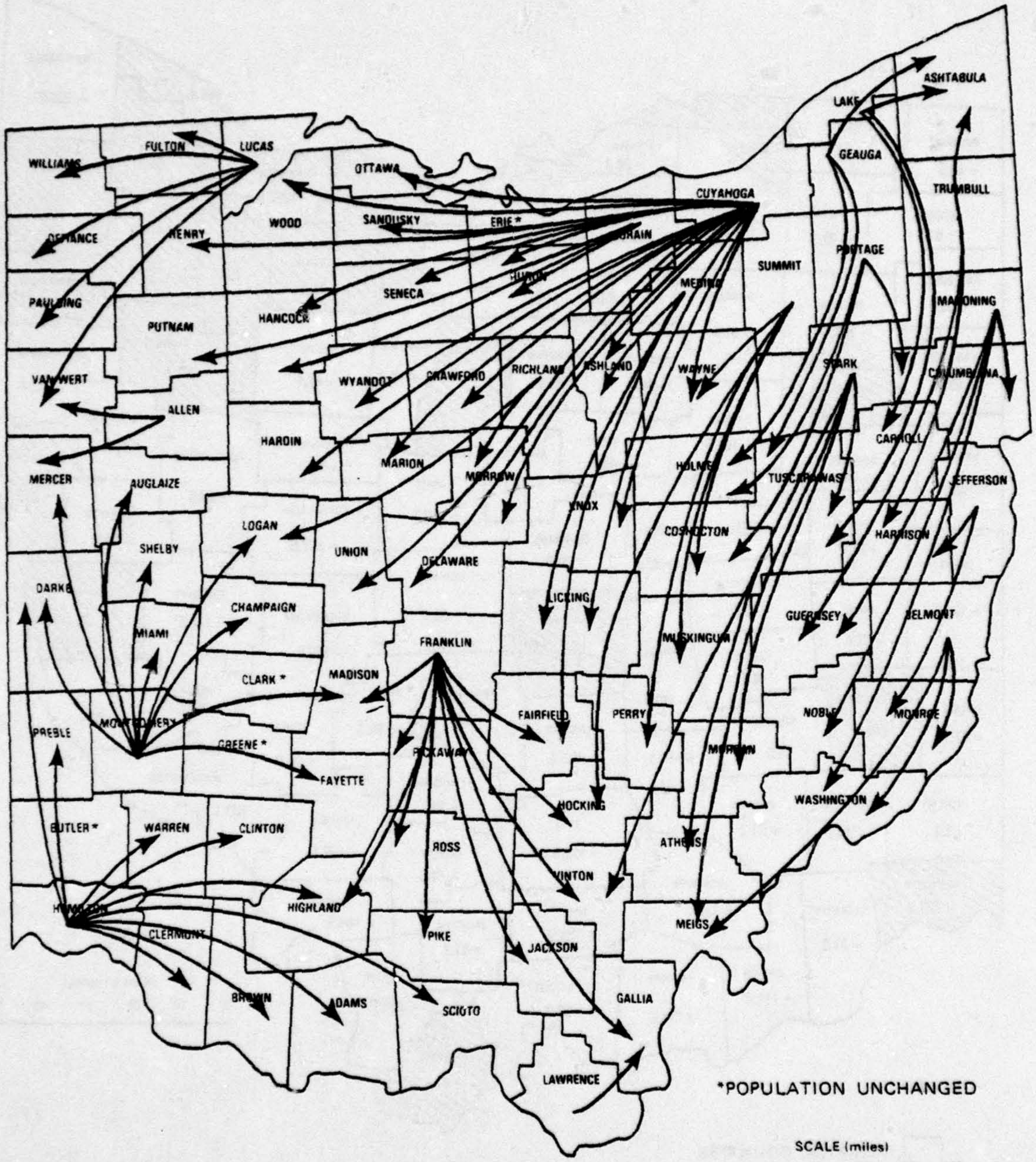


FIGURE 4. RELOCATION DESTINATIONS IN OHIO

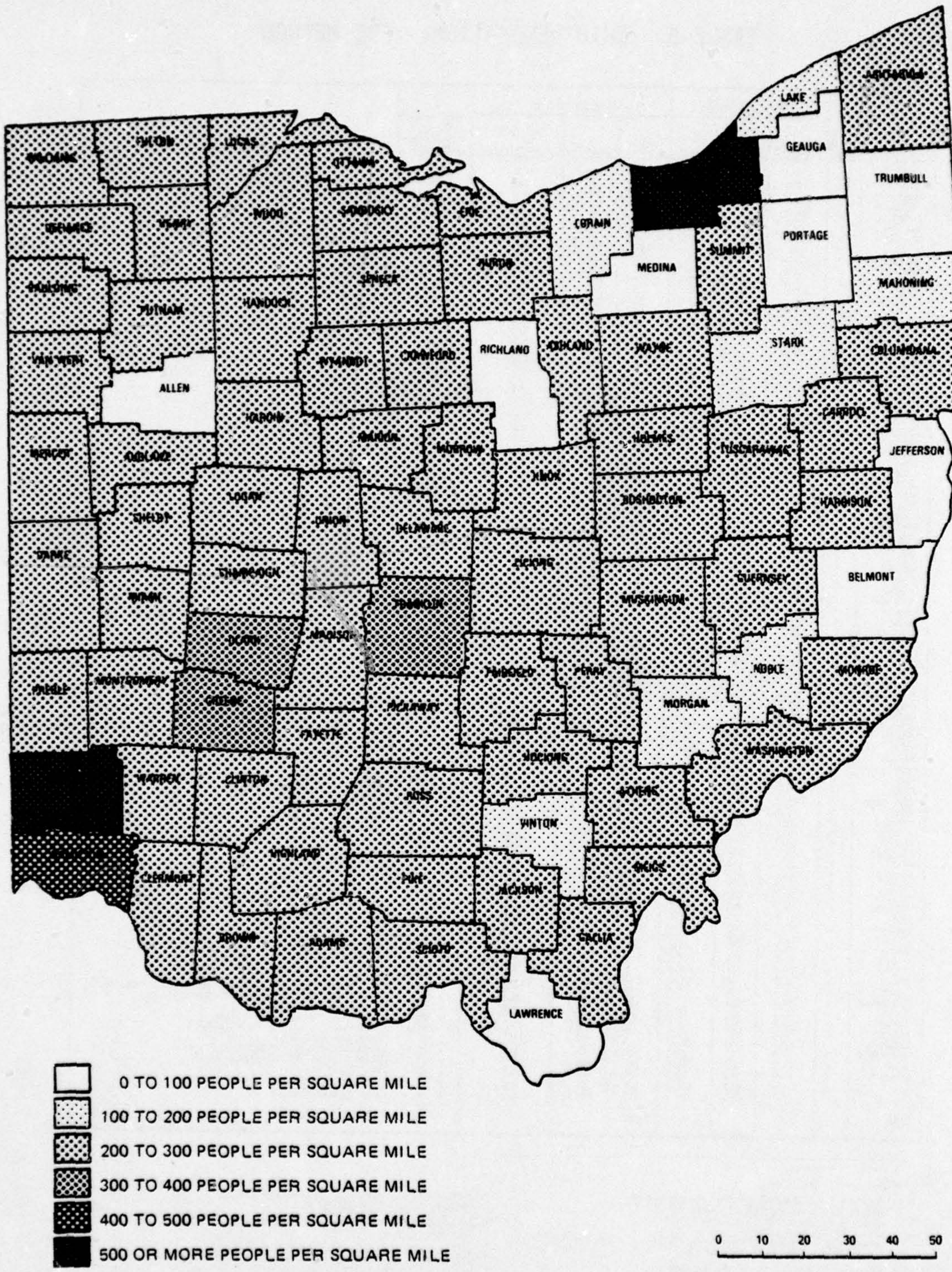


FIGURE 5. RELOCATED POPULATION DENSITY OF OHIO, SPC METHOD
(Total Population = 10.7 million)

TABLE 3. OHIO RELOCATION: SPC METHOD

County	Category[a]	Before Relocation: Population(K)	Before Relocation: Area (mi²)[b]	Before Relocation: Pop/mi²	After Relocation: Population(K)	After Relocation: Pop/mi²	Population Ratio (Final/Initial)	Population Change (Final Minus Initial(K))	Origin/Destination (K)
ADAMS	N	22.3	587	38.0	133.8	227.9	6.0	+ 111.5	From Hamilton (111.5)
ALLEN	R	108.1	410	263.7	21.6	52.7	0.2	- 86.5	To Mercer (32.4), Van Wert (54.1)
ASHLAND	N	44.0	424	103.8	122.3	288.5	2.8	+ 78.3	From Cuyahoga (68.6), Medina (9.7)
ASHTABULA	N	101.3	700	144.7	201.9	288.5	2.0	+ 100.6	From Geauga (13.1), Lake (40.5), Trumbull (47.0)
ATHENS	N	50.2	504	99.6	145.4	288.5	2.9	+ 95.2	From Stark (95.2)
AUGLAIZE	N	42.3	400	105.8	115.4	288.5	2.7	+ 73.1	From Montgomery (73.1)
BELMONT	R	82.2	534	153.9	16.4	30.7	0.2	- 65.8	To Meigs (31.8), Monroe (10.3), Washington (23.7)
BROWN	N	29.6	490	60.4	141.4	288.5	4.8	+ 111.8	From Hamilton (111.8)
BUTLER	N	246.0	471	522.3	246.0	522.3	1.0	0.0	Unchanged
CARROLL	N	25.0	390	64.1	112.5	288.5	4.5	+ 87.5	From Lake (87.5)
CHAMPAIGN	N	31.8	432	73.6	124.6	288.5	3.9	+ 92.8	From Montgomery (92.8)
CLARK	N	151.6	402	377.1	151.6	377.1	1.0	0.0	Unchanged
CLERMONT	N	110.3	458	240.8	132.1	288.5	1.2	+ 21.8	From Hamilton (21.8)
CLINTON	N	32.1	410	78.3	118.3	288.5	3.7	+ 86.2	From Hamilton (86.2)
COLUMBIANA	N	111.7	534	209.2	154.1	288.5	1.4	+ 42.4	From Mahoning (29.1), Portage (13.3)
COSHOCTON	N	34.6	562	61.6	162.1	288.5	4.7	+ 127.5	From Portage (30.3), Summit (97.2)
CRAWFORD	N	50.6	404	125.2	116.5	288.5	2.3	+ 65.9	From Cuyahoga (65.9)
CUYAHOGA	R	1,578.5	456	3,461.6	315.7	692.3	0.2	-1262.8	c
DARKE	N	53.8	605	88.9	174.5	288.5	3.2	+ 120.7	From Hamilton (98.2), Montgomery (22.5)
DEFIANCE	N	37.1	412	90.0	118.9	288.5	3.2	+ 81.8	From Lucas (81.8)
DELAWARE	N	49.8	450	110.7	129.8	288.5	2.6	+ 80.0	From Cuyahoga (80.0)
ERIE	N	77.6	264	293.9	77.6	288.5	1.0	0.0	Unchanged
FAIRFIELD	N	85.9	505	170.1	145.7	288.5	1.7	+ 59.8	From Franklin (12.6), Medina (47.2)
FAYETTE	N	25.9	404	64.1	116.5	288.5	4.5	+ 90.6	From Montgomery (90.6)
FRANKLIN	R	859.5	538	1,597.6	171.9	319.5	0.2	- 687.6	d
FULTON	N	35.8	407	88.0	117.4	288.5	3.3	+ 81.6	From Lucas (81.6)
GALLIA	N	29.7	471	63.1	135.9	288.5	4.6	+ 106.2	From Franklin (59.1), Lawrence (47.1)
GEAUGA	R	68.6	407	168.6	13.7	33.7	0.2	- 54.9	To Ashtabula (13.1), Holmes (35.1), Tuscarawas (6.7)
GREENE	N	130.0	415	313.3	130.0	313.2	1.0	0.0	Unchanged
GUERNSEY	N	39.4	528	74.6	152.3	288.5	3.9	+ 112.9	From Mahoning (44.2), Trumbull (68.7)
HAMILTON	R	879.7	414	2,124.9	175.9	424.9	0.2	- 703.8	e
HANCOCK	N	61.8	532	116.2	153.5	288.5	2.5	+ 91.7	From Cuyahoga (11.9), Lorain (79.8)
HARDIN	N	31.9	467	68.3	134.7	288.5	4.2	+ 102.8	From Cuyahoga (102.8)
HARRISON	N	17.9	401	44.6	107.4	267.8	6.0	+ 89.5	From Jefferson (9.0), Trumbull (80.5)
HENRY	N	27.7	416	66.6	120.0	288.5	4.3	+ 92.3	From Cuyahoga (92.3)
HIGHLAND	N	31.0	549	56.5	158.4	288.5	5.1	+ 127.4	From Franklin (63.4), Hamilton (64.0)
HOCKING	N	21.4	421	50.8	121.5	288.5	5.7	+ 100.1	From Franklin (15.2), Summit (84.9)
HOLMES	N	25.2	424	59.4	122.3	288.5	4.9	+ 97.1	From Geauga (35.1), Portage (62.0)
HURON	N	52.1	497	104.8	143.4	288.5	2.8	+ 91.3	From Cuyahoga (65.9), Lorain (25.4)
JACKSON	N	29.7	419	70.9	120.9	288.5	4.1	+ 91.2	From Franklin (91.2)
JEFFERSON	R	94.0	411	228.7	18.8	45.7	0.2	- 75.2	To Harrison (9.0), Monroe (66.2)
KNOX	N	42.5	531	80.0	153.2	288.5	3.6	+ 110.7	From Cuyahoga (110.7)
LAKE	R	211.1	231	913.9	42.2	182.7	0.2	- 168.9	To Ashtabula (40.5), Carroll (87.5), Tuscarawas (40.9)
LAWRENCE	R	58.9	456	129.2	11.8	25.9	0.2	- 47.1	To Gallia (47.1)
LICKING	N	114.8	686	167.3	197.9	288.5	1.7	+ 83.1	From Cuyahoga (58.6), Medina (24.5)
LOGAN	N	37.2	460	80.9	132.7	288.5	3.6	+ 95.5	From Montgomery (4.0), Richland (91.5)
LORAIN	R	266.4	495	538.2	53.3	107.7	0.2	- 213.1	To Hancock (79.8), Huron (25.4), Putnam (107.9)
LUCAS	R	479.7	343	1,398.5	95.9	279.6	0.2	- 383.8	f
MADISON	N	32.7	463	70.6	133.6	288.5	4.1	+ 100.9	From Franklin (84.1), Montgomery (16.8)
MAHONING	R	289.6	415	697.8	57.9	139.5	0.2	- 231.7	g
MARION	N	67.2	405	165.9	116.8	288.5	1.7	+ 49.6	From Cuyahoga (49.6)
MEDINA	R	101.8	425	239.5	20.4	48.0	0.2	- 81.4	To Ashland (9.7), Fairfield (47.2), Licking (24.5)
MEIGS	N	21.5	436	49.3	125.8	288.5	5.9	+ 104.3	From Belmont (31.8), Stark (72.5)
MERCER	N	37.4	444	84.2	128.1	288.5	3.4	+ 90.7	From Allen (32.4), Montgomery (58.3)
MIAMI	N	87.0	407	213.8	117.4	288.5	1.4	+ 30.4	From Montgomery (30.4)
MONROE	N	15.3	456	33.6	91.8	201.3	6.0	+ 76.5	From Belmont (10.3), Jefferson (66.2)
MONTGOMERY	R	582.7	459	1,269.5	116.5	253.8	0.2	- 466.2	h
MORGAN	N	13.2	420	31.4	79.2	188.6	6.0	+ 66.0	From Stark (66.0)
MORROW	N	24.1	403	59.8	116.3	288.5	4.8	+ 92.2	From Cuyahoga (79.7), Richland (12.5)
MUSKINGUM	N	81.2	651	124.7	187.8	288.5	2.3	+ 106.6	From Summit (106.6)
NOBLE	N	11.4	398	28.6	68.4	171.9	6.0	+ 57.0	From Mahoning (57.0)
OTTAWA	N	39.0	261	149.4	75.3	288.5	2.0	+ 36.3	From Cuyahoga (36.3)
PAULDING	N	19.8	417	47.5	118.8	284.9	6.0	+ 99.0	From Lucas (99.0)
PERRY	N	30.0	410	73.2	118.3	288.5	3.9	+ 88.3	From Summit (88.3)
PICKAWAY	N	44.1	504	87.5	145.4	288.5	3.3	+ 101.3	From Franklin (101.3)
PIKE	N	20.9	443	47.2	125.4	283.1	6.0	+ 104.5	From Franklin (104.5)
PORTAGE	R	132.0	495	266.7	26.4	53.3	0.2	- 105.6	To Columbiana (13.3), Coshocton (30.3), Holmes (62.0)
PREBLE	N	35.9	427	84.1	123.2	288.5	3.4	+ 87.3	From Hamilton (87.3)
PUTNAM	N	32.3	486	66.5	140.2	288.5	4.3	+ 107.9	From Lorain (107.9)
RICHLAND	R	130.0	496	262.1	26.0	52.4	0.2	- 104.0	To Logan (91.5), Morrow (12.5)
ROSS	N	61.6	687	89.7	198.2	288.5	3.2	+ 136.6	From Franklin (136.6)
SANDUSKY	N	62.3	409	152.3	118.0	288.5	1.9	+ 55.7	From Cuyahoga (55.7)
SCIOTO	N	82.5	608	135.7	175.4	288.5	2.1	+ 92.9	From Hamilton (92.9)
SENECA	N	59.5	551	108.0	159.0	288.5	2.7	+ 99.5	From Cuyahoga (99.5)
SHELBY	N	40.0	408	98.0	117.7	288.5	2.9	+ 77.7	From Montgomery (77.7)
STARK	R	377.2	576	654.9	75.4	130.9	0.2	- 301.8	i
SUMMIT	R	535.0	408	1,311.3	107.0	262.2	0.2	- 428.0	j
TRUMBULL	R	245.3	608	403.4	49.1	80.8	0.2	- 196.2	To Ashtabula (47.0), Guernsey (68.7), Harrison (80.5)
TUSCARAWAS	N	80.4	569	141.3	164.2	288.5	2.0	+ 83.8	From Geauga (6.7), Lake (40.9), Stark (36.2)
UNION	N	27.1	434	62.4	125.2	288.5	4.6	+ 98.1	From Cuyahoga (98.1)
VAN WERT	N	29.0	409	70.9	118.0	288.5	4.1	+ 89.0	From Allen (54.1), Lucas (34.9)
VINTON	N	10.3	411	25.1	61.8	150.4	6.0	+ 51.5	From Franklin (19.6), Stark (31.9)
WARREN	N	87.6	408	214.7	117.7	288.5	1.3	+ 30.1	From Hamilton (30.1)
WASHINGTON	N	59.8	641	93.3	184.9	288.5	3.1	+ 125.1	From Belmont (23.7), Mahoning (101.4)
WAYNE	N	94.7	561	168.8	161.8	288.5	1.7	+ 67.1	From Cuyahoga (16.1), Summit (51.0)
WILLIAMS	N	34.9	421	82.9	121.4	288.5	3.5	+ 86.5	From Lucas (86.5)
WOOD	N	101.9	619	164.6	178.6	288.5	1.8	+ 76.7	From Cuyahoga (76.7)
WYANDOT	N	22.7	406	55.9	117.1	288.5	5.2	+ 94.4	From Cuyahoga (94.4)
TOTAL		10,689.2			10,689.2			0.0	

[a] R = Risk, N = Nonrisk

[b] "Miles" are statute miles.

[c] To Ashland (68.6), Crawford (65.9), Delaware (80.0), Hancock (11.9), Hardin (102.8), Henry (92.3), Huron (65.9), Knox (110.7), Licking (58.6), Marion (49.6), Morrow (79.7), Ottawa (36.3), Sandusky (55.7), Seneca (99.5), Union (98.1), Wayne (16.1), Wood (76.7), Wyandot (94.4)

[d] To Fairfield (12.6), Gallia (59.1), Highland (63.4), Hocking (15.2), Jackson (91.2), Madison (84.1), Pickaway (101.3), Pike (104.5), Ross (136.6), Vinton (19.6)

[e] To Adams (111.5), Brown (111.8), Clermont (21.8), Clinton (86.2), Darke (98.2), Highland (64.0), Preble (87.3), Scioto (92.9), Warren (30.1)

[f] To Defiance (81.8), Fulton (81.6), Paulding (99.0), Van Wert (34.9), Williams (86.5)

[g] To Columbiana (29.1), Guernsey (44.2), Noble (57.0), Washington (101.4)

[h] To Auglaize (73.1), Champaigne (92.8), Darke (22.5), Fayette (90.6), Logan (4.0), Madison (16.8), Mercer (58.3), Miami (30.4), Shelby (77.7)

[i] To Athens (95.2), Meigs (72.5), Morgan (66.0), Tuscarawas (36.2), Vinton (31.9)

[j] To Coshocton (97.2), Hocking (84.9), Muskingum (106.6), Perry (88.3), Wayne (51.0)

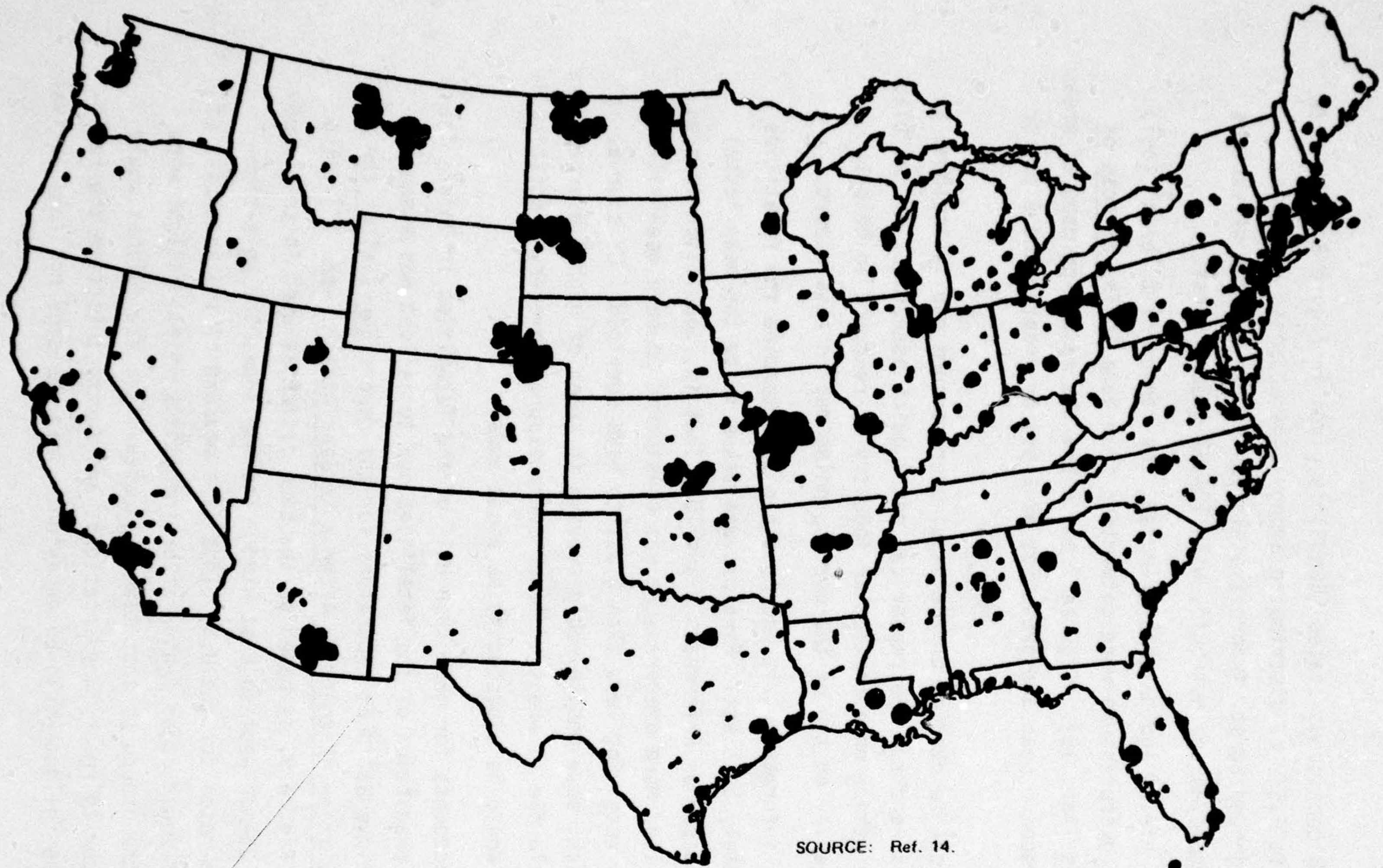
areas in the 48 contiguous states (CONUS) is given in Figure 6. The size of the attack is 6,559 MT distributed among 1,444 weapons. Of this, 5,051 MT were ground burst. Approximately 224 MT, in weapons of various yields, were employed against Ohio, with 124 MT ground burst.

Using the yields and heights-of-burst, the ranges of 2 lb/in^2 (psi) and 5-psi peak overpressure were determined from data in The Effects of Nuclear Weapons [Ref. 16]. Figures 7 and 8 are the resulting maps of areas in Ohio that receive peak overpressures of 2 psi or greater and 5 psi or greater.

A clear acetate overlay of the 5-psi overpressure map is included at the end of this report. The reader can get a quick assessment of the blast effects of the attack on a particular industry or resource in Ohio by placing the overlay on top of the corresponding map in this report.

From this information, it was possible to determine the fatalities caused immediately by blast. Five psi was taken to be the mean lethal overpressure, based on References 9 and 10. That is, population in areas receiving 5 psi or more overpressure was considered to have been killed, and population receiving less than 5 psi to have survived. Of course, in an actual attack, some people would survive in areas of higher overpressure while some would die in areas of lower overpressure; however, statistically these numbers would be expected to be about equal.

Fallout accounts for more than half of the fatalities in Ohio. The basis for the prediction of the fatalities due to fallout was a map prepared by Oak Ridge National Laboratory for the report Survival of the Relocated Population of the U.S. After a Nuclear Attack [Ref. 17]. The map, shown in Figure 9, is based on the same attack as used in this study and assumes a 25-mph west to east wind. The map shows the unit-time-reference-dose-rates for the U.S. This is a measure of the intensity of radiation that would occur 1 hour after the attack if all fallout were deposited on the ground by that time. In actuality, the fallout would take much longer to reach many locations, and during this time the radioactivity of the fallout would be decaying. This map does not take arrival



SOURCE: Ref. 14.

FIGURE 6. CONUS BLAST AREAS

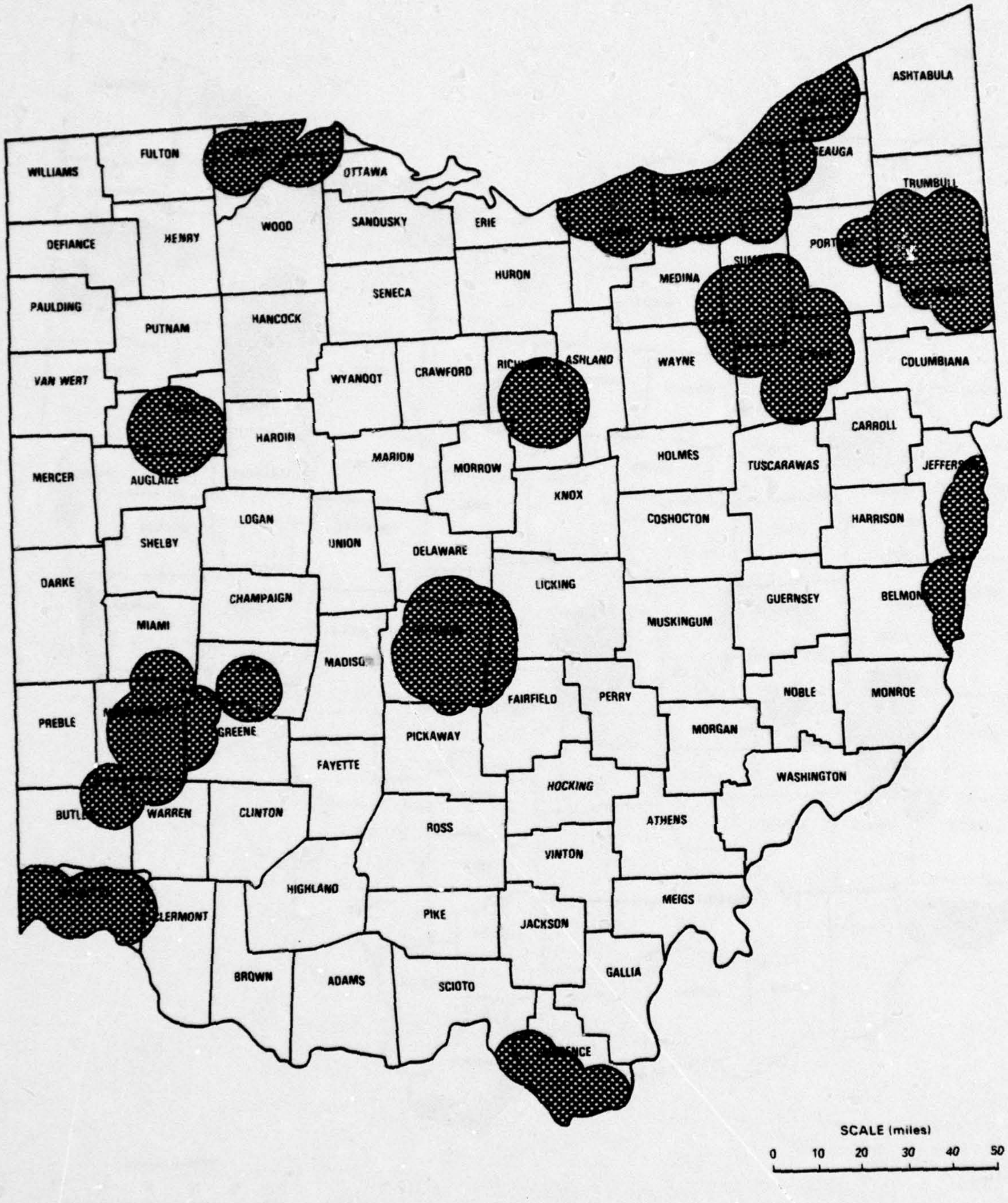


FIGURE 7. OHIO AREAS RECEIVING 2 PSI OR GREATER

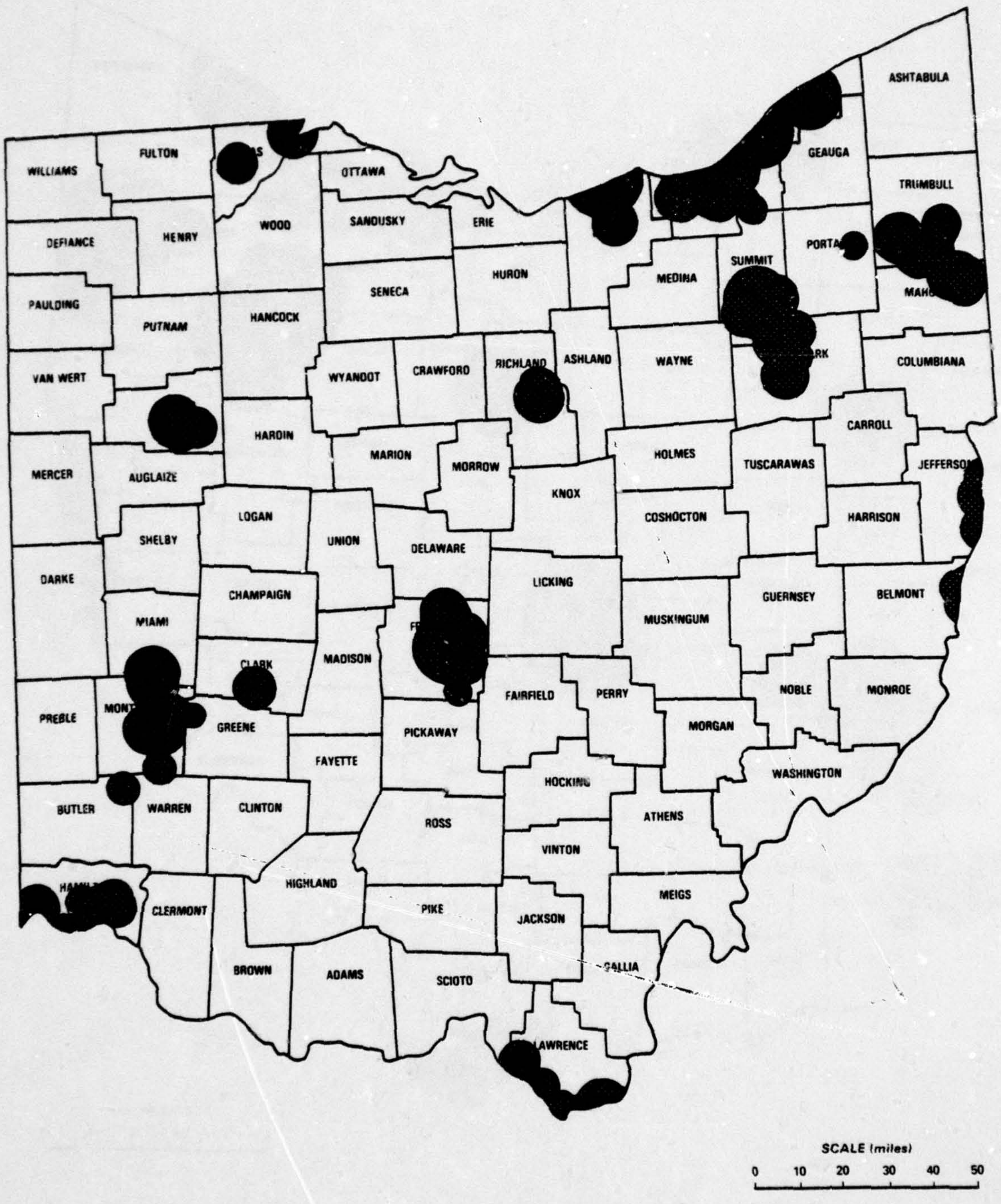
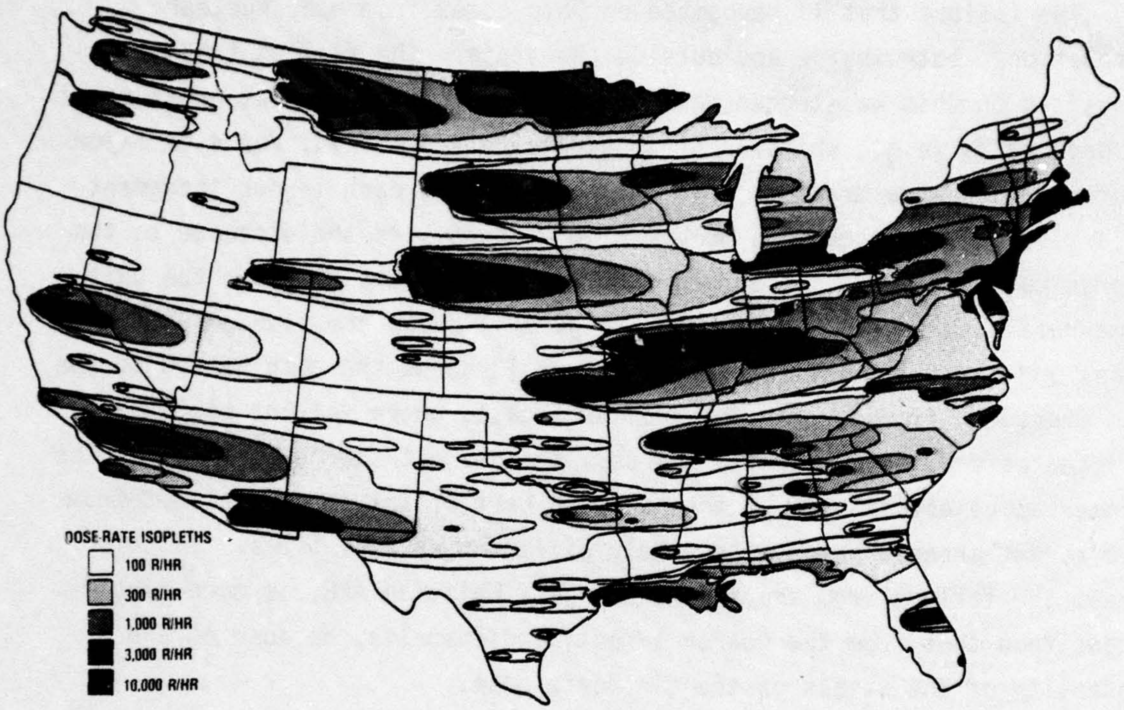


FIGURE 8. OHIO AREAS RECEIVING 5 PSI OR GREATER



SOURCE: Ref. 16

FIGURE 9. CONUS UNIT TIME REFERENCE DOSE RATES

time into account. Thus, to estimate the actual accumulated dose at any point, which is the quantity associated with biological damage, assumptions must be made about the arrival times of the fallout.

The fallout that is deposited on Ohio comes from many nuclear detonations, both inside and outside the state. The fallout that is deposited on Ohio was traced back to the several major target areas where it originates (e.g., Whiteman AFB, Chicago, etc.). Then, for each major source, zones were drawn in Ohio corresponding to each 1-hour increment of arrival time, based on a 25-mph wind velocity and the distance to the approximate center of the source target area. Figure 10 shows the unit-time-reference-dose-rates for Ohio; Figure 11 shows the time of arrival zones and the fallout sources; and Figure 12 shows the combination of the two preceding figures. In any ambiguous case, where fallout could have originated from either of two sources, the nearest source was chosen (the conservative estimate). In the southern part of the state, fallout from two target areas overlap with widely different arrival times. In this area, the fallout from the further target, Whiteman AFB, is more significant than that from the nearer target, Indianapolis, because of the intensity of the attack on the air force base.

From the times of arrival of the fallout, the total accumulated doses were calculated for each region using data from Reference 15. Figure 13 shows the accumulated dose over the first 4 days, and Figure 14 shows the dose for 14 days.[1]

Once the fallout doses and blast areas were determined, the resulting fatalities could be predicted for various behaviors of the population. For the purposes of the study, it was assumed that the population had evacuated the risk areas according to the previously discussed CRP as developed by SPC. It was also assumed that the population stayed in shelters (average PF of 50) for 2 weeks, and then emerged, whether it was safe or not.

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[1]In various parts of this report, depending on the source documents, doses are discussed in terms of roentgens, rads, and rems. For fallout (gamma) radiation, these are all essentially the same. (See Appendix.)

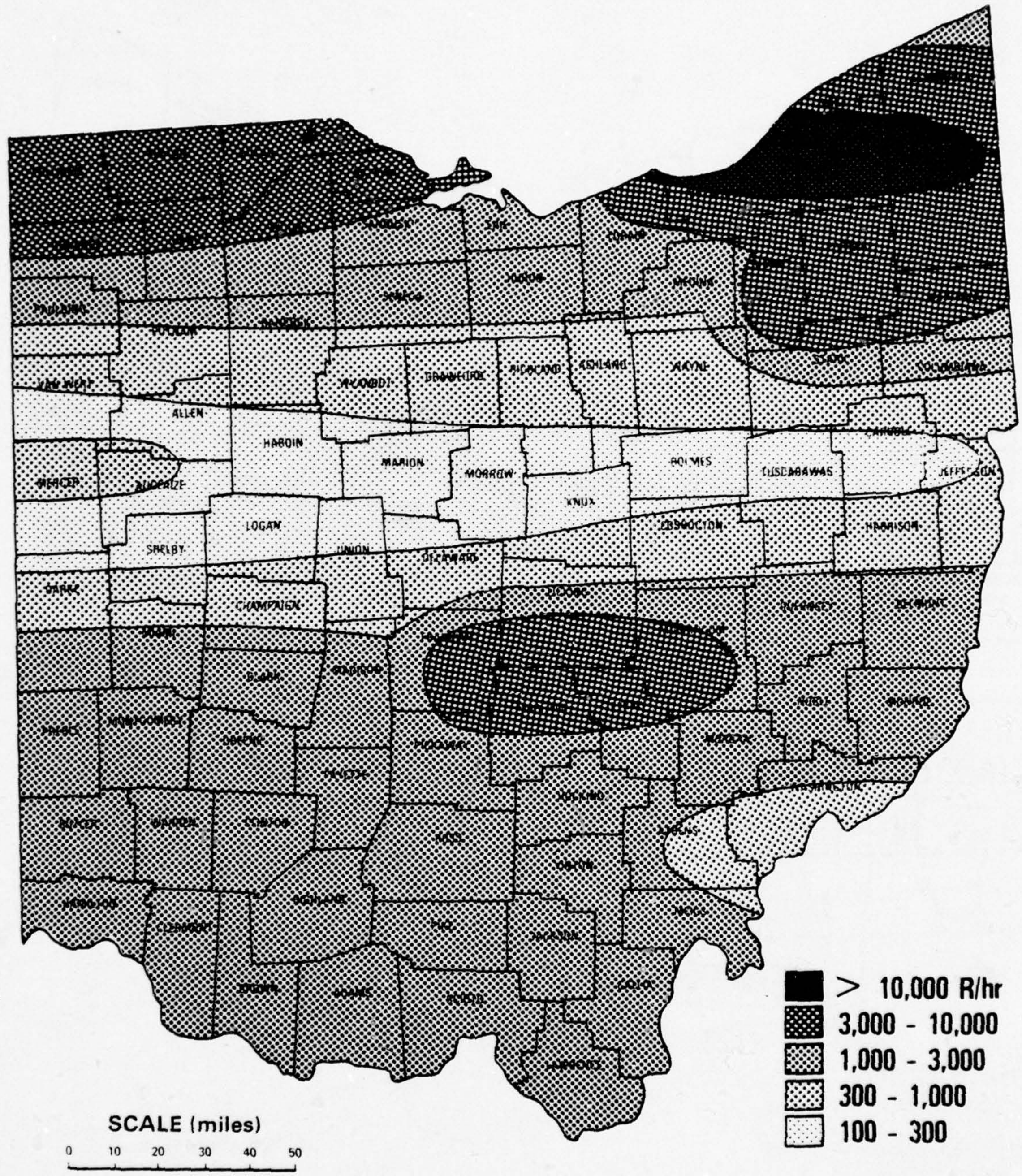


FIGURE 10. OHIO UNIT TIME REFERENCE DOSE RATES

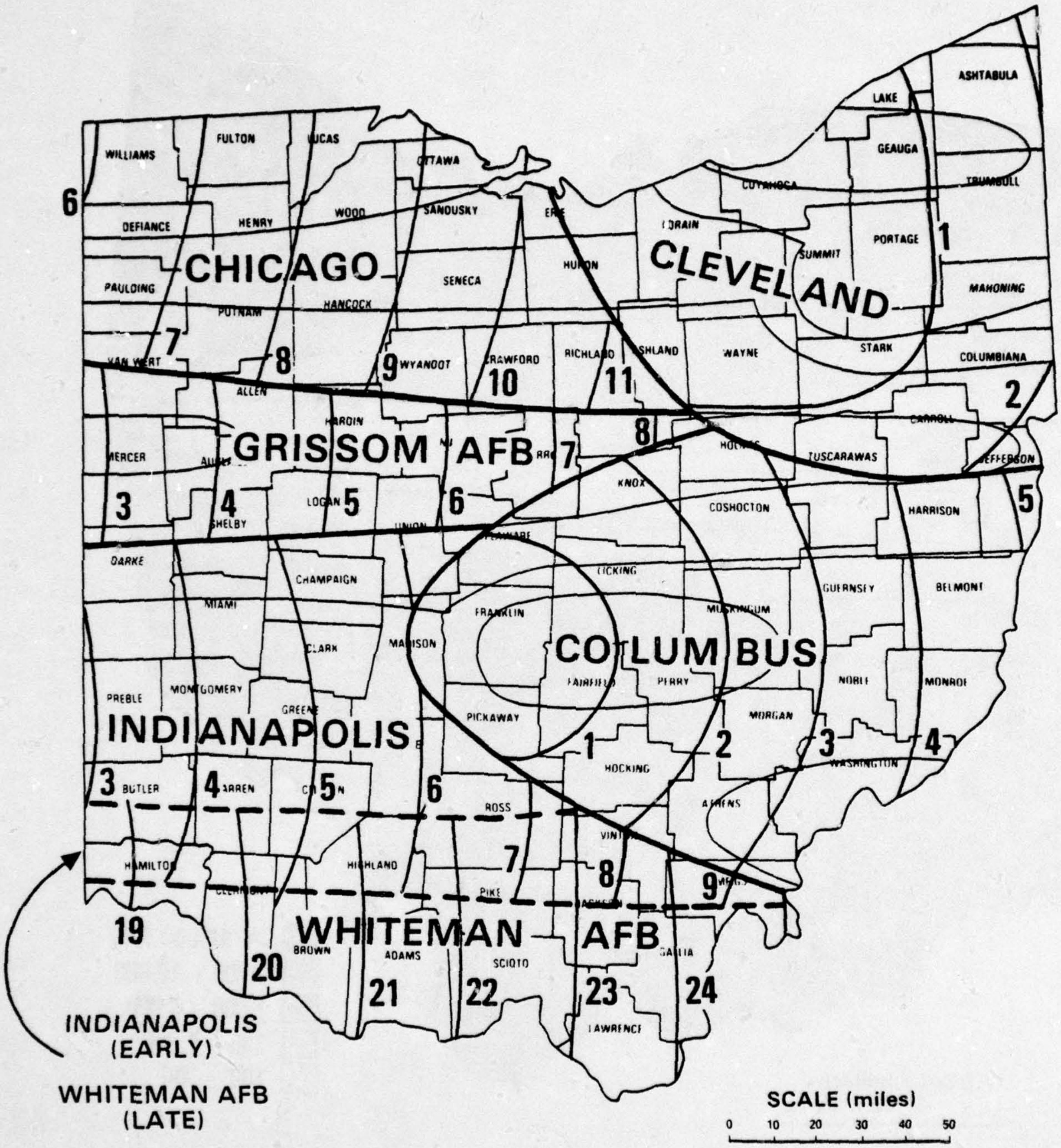


FIGURE 11. PRIMARY SOURCES OF FALLOUT AND ARRIVAL TIMES IN HOURS

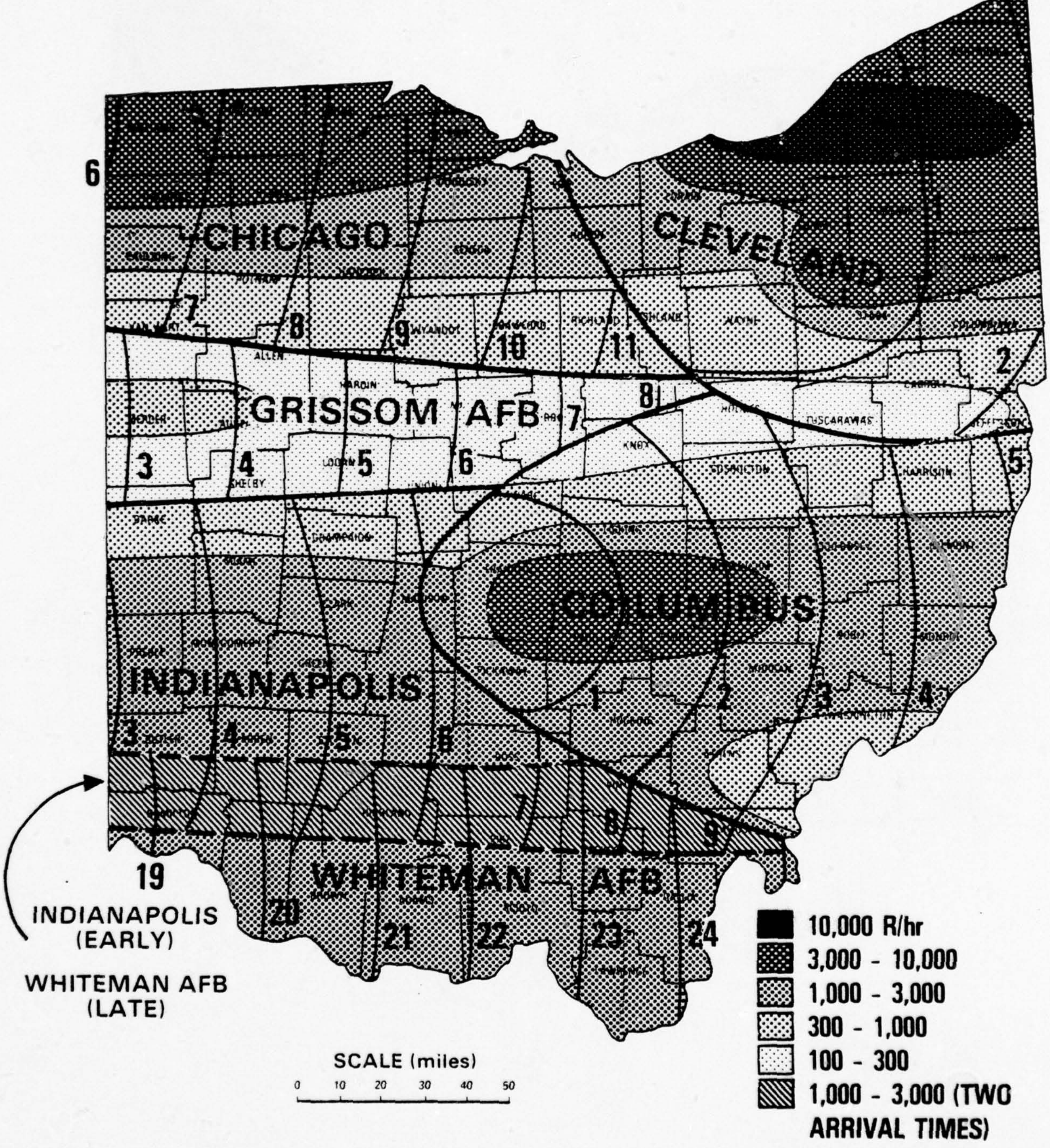


FIGURE 12. UNIT TIME REFERENCE DOSE RATES (WITH PRIMARY SOURCES AND ARRIVAL TIMES IN HOURS)

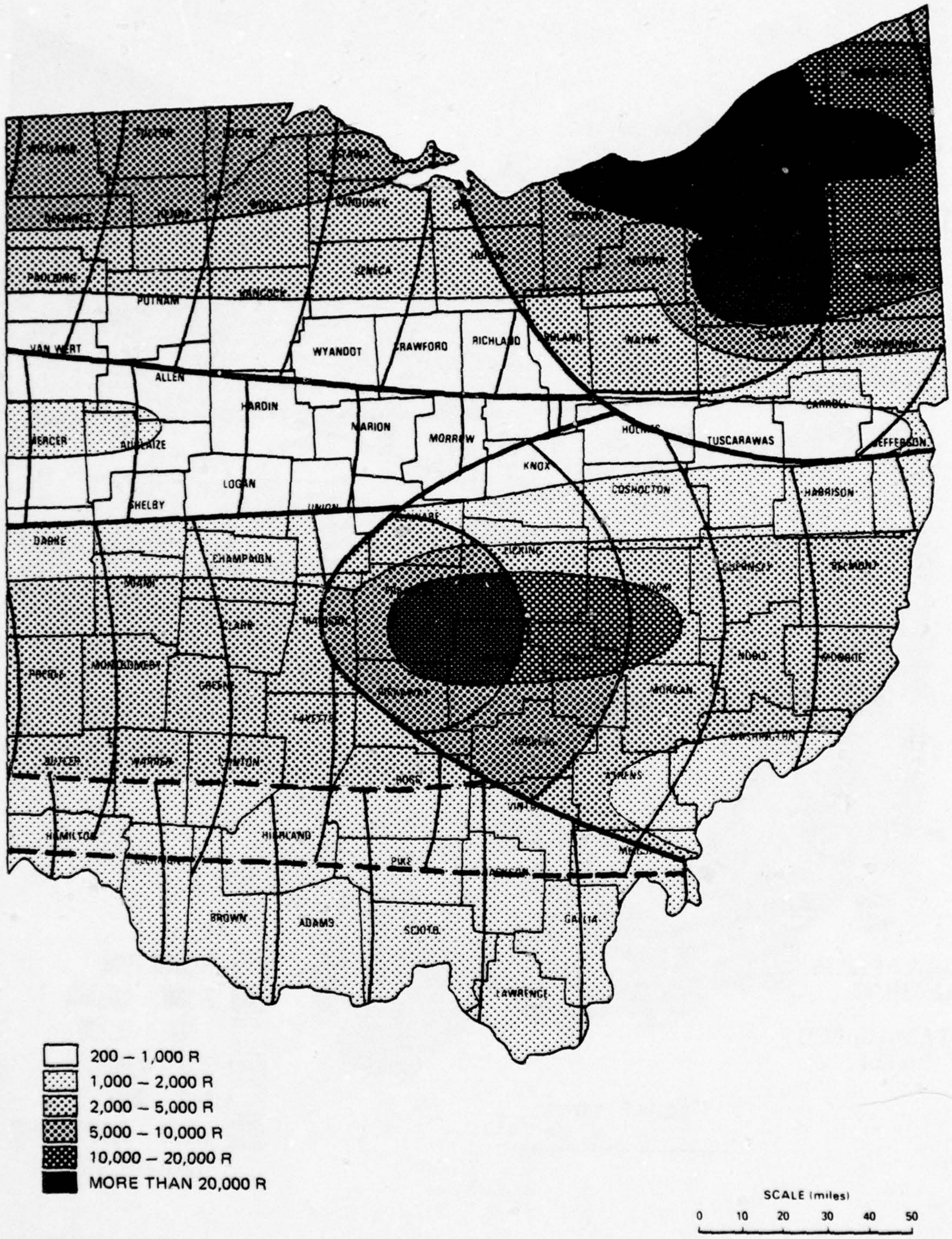


FIGURE 13. ACCUMULATED FOUR-DAY DOSE (PF = 1), ROENTGENS

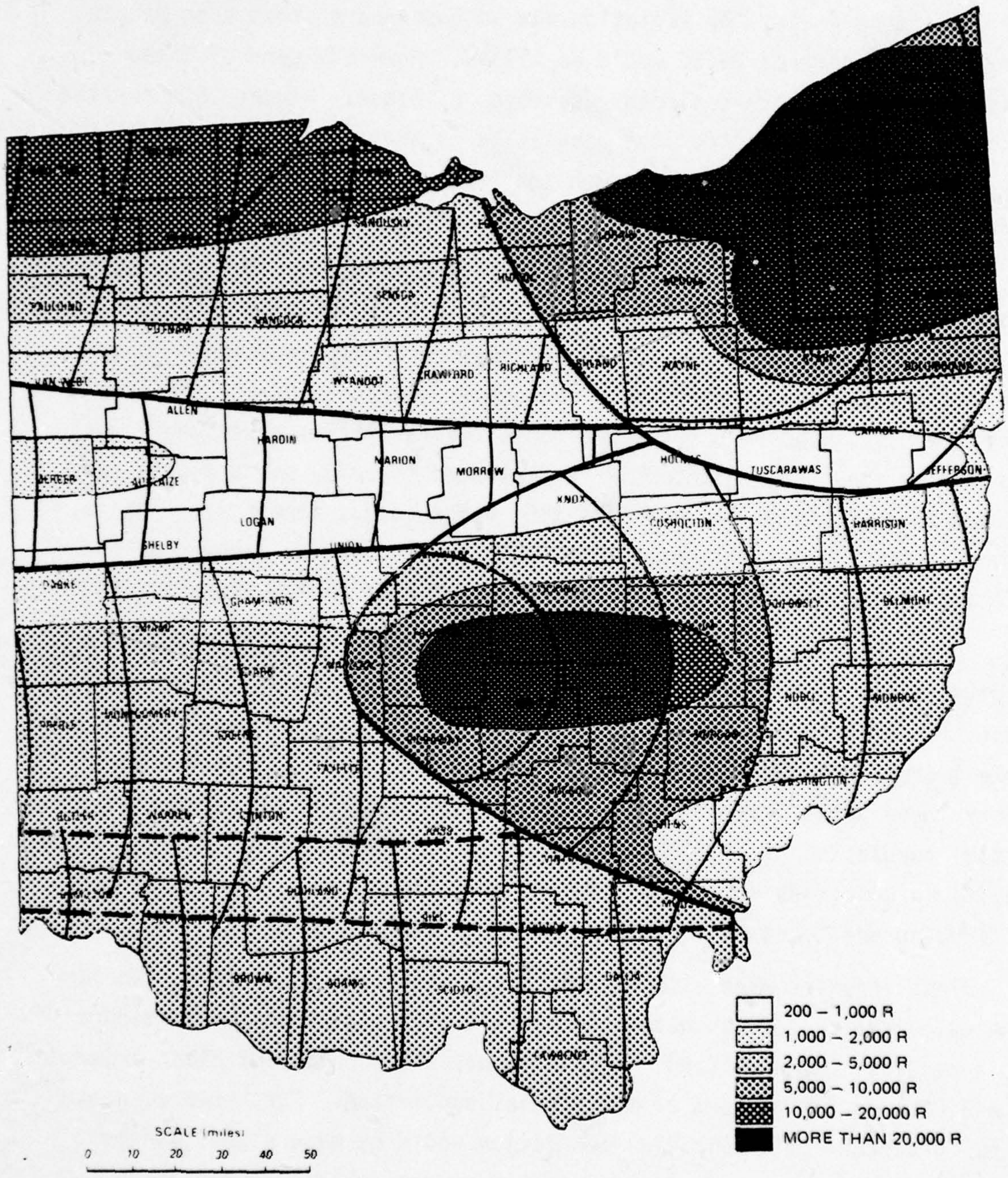


FIGURE 14. ACCUMULATED TWO-WEEK DOSE (PF = 1), ROENTGENS

In certain areas, the radiation was intense enough that even people in fallout shelters of PF 50 would be killed. However, some of these areas correspond to areas already destroyed by blast. Figure 15 shows the deaths caused by fallout for the population in shelters after 2 weeks. The criteria for fatalities are based on the "radiation penalty table" in Reference 18.

In some areas, there would be further fatalities when the population emerged from the shelters. This is because in areas of high fallout intensity, the population would have already received significant doses while in the shelters, and outside dose rates would not be at safe levels after 2 weeks. Figure 16 shows the radiation fatalities after the 2 weeks outside the shelters. Outdoors PF was assumed to be 3, since people were assumed to be occupied outdoors for long hours (e.g., farming). Finally, Figure 17 shows the total doses that would be received by people who had followed the pattern of two weeks at PF 50 followed by two weeks at PF 3.

So far, the data presented have been in terms of percent fatalities in given areas of the state. These results were applied to the assumed population distribution to calculate the actual numbers of fatalities. Table 4 shows the number of people killed by blast and fallout for each county. The total fatalities in Ohio were 1,900,000, or 18 percent of the initial population of 10,700,000. Figure 18 shows the surviving population density in Ohio. As can be seen in the map, almost total fatalities are suffered in the counties that comprise the Cleveland area.

Blast injuries were also estimated for the state as a whole. These were calculated under the assumption that the mean casualty overpressure would be 2 psi [Refs. 9, 10]. The total estimated number of blast injured is 615,000, or 5.7 percent of the initial population. Furthermore, about 10 to 15 percent of the initial population would be made significantly ill from fallout. This was calculated using the determined radiation doses and the radiation casualty curve in Reference 19. About half of the blast-injured people would be in this category.

Thus, about 3 percent of the initial population would receive both blast injuries and "fallout injuries"; many of these people might die.

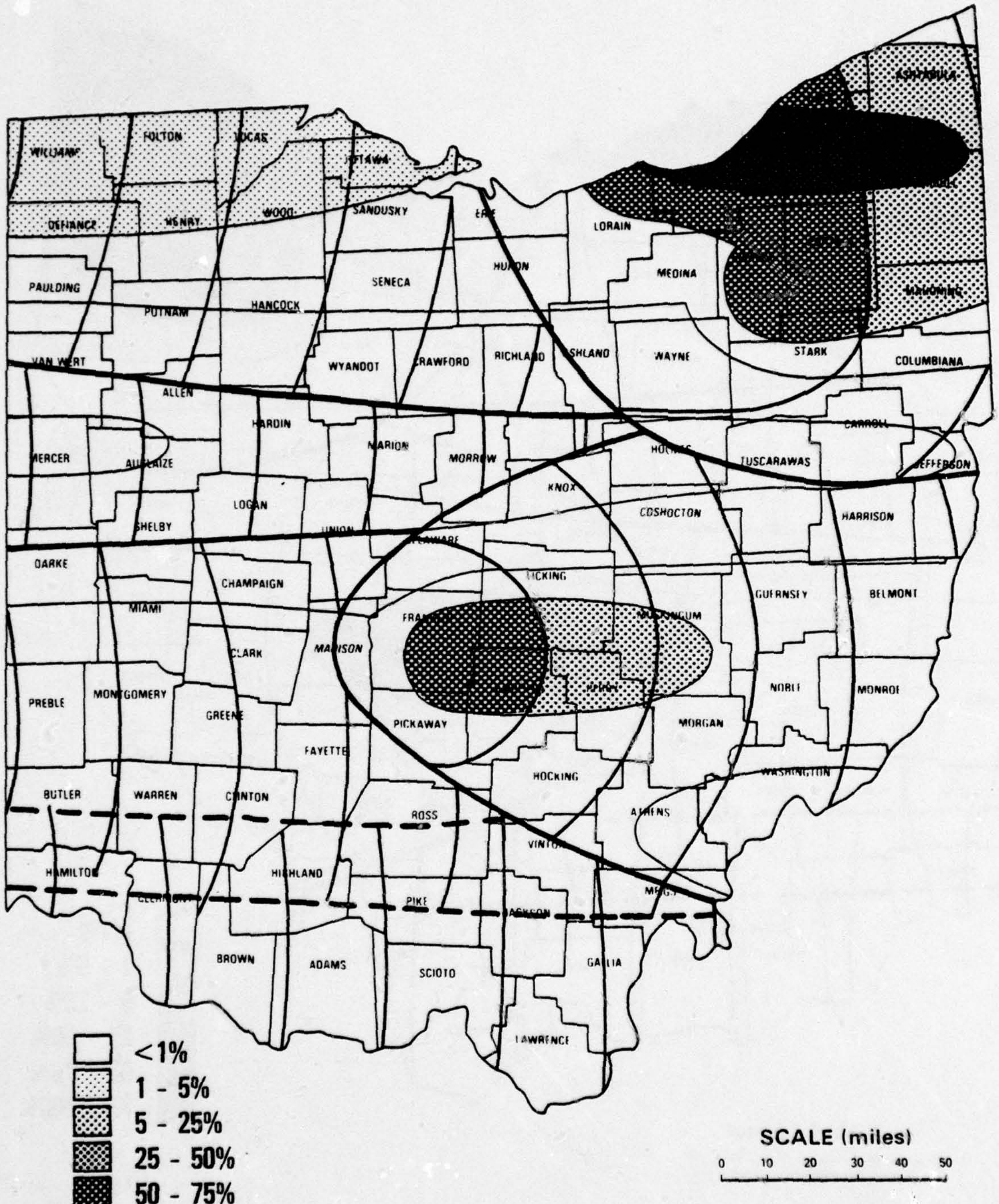


FIGURE 15. DEATHS IN FALLOUT SHELTERS OF PF 50 IN TWO WEEKS

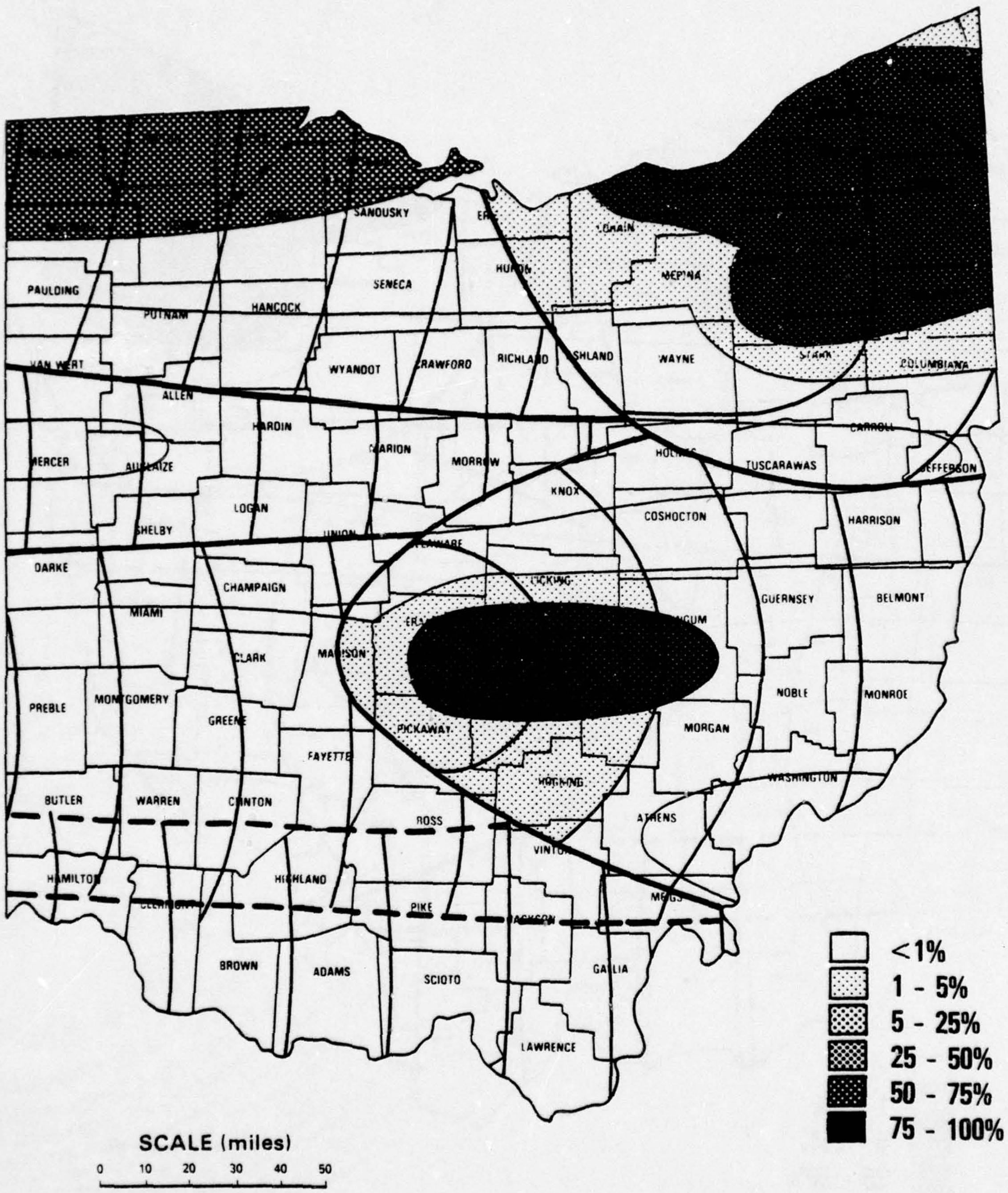


FIGURE 16. DEATHS AFTER TWO WEEKS IN FALLOUT SHELTERS OF PF 50 FOLLOWED BY TWO WEEKS OUTSIDE AT PF 3

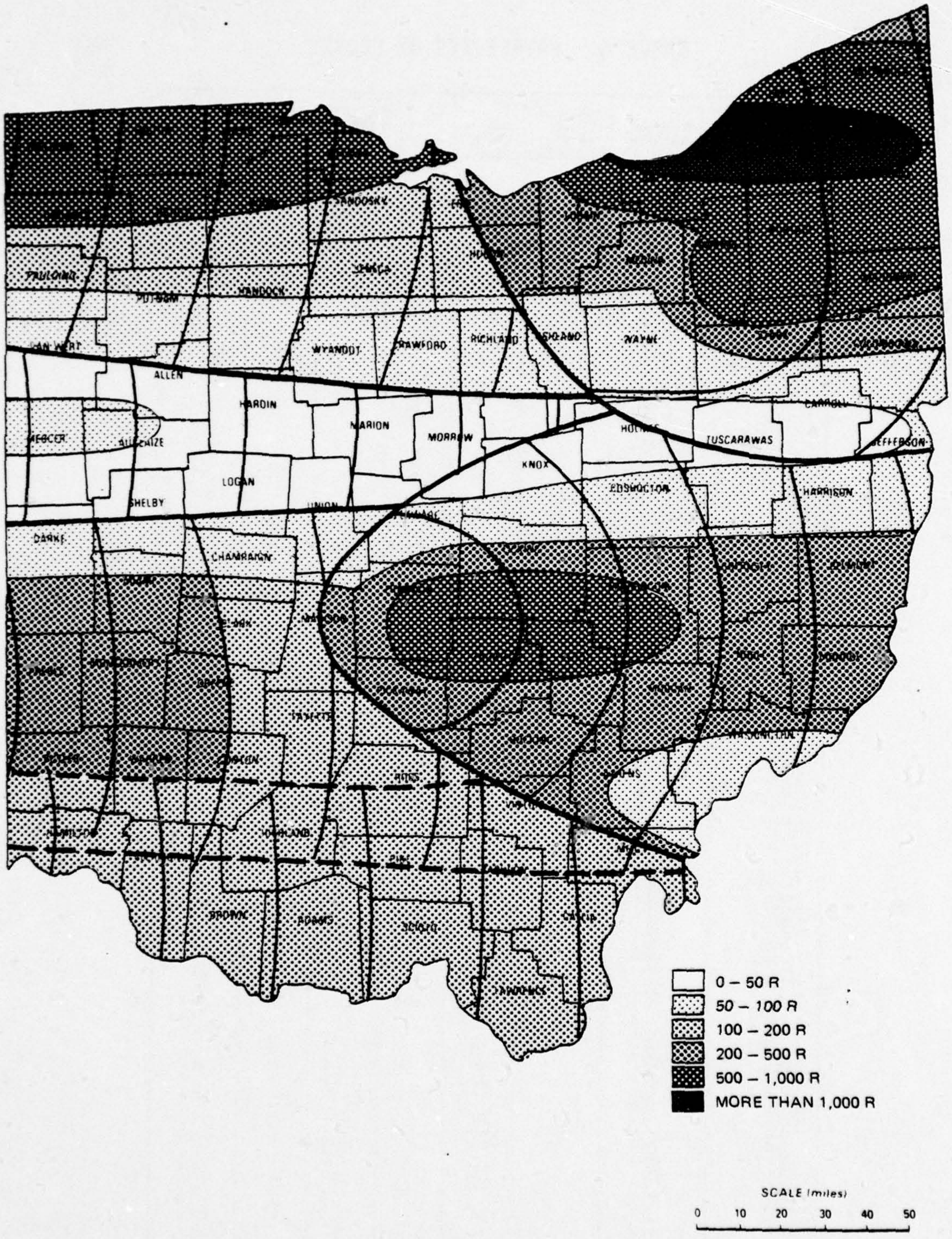


FIGURE 17. ACCUMULATED DOSE FOR TWO WEEKS IN SHELTER (PF = 50) FOLLOWED BY TWO WEEKS OUTSIDE SHELTER (PF = 3), ROENTGENS

TABLE 4. FATALITIES BY COUNTY

County	Relocated Population (K)	Percent of County Covered by 5-psi Blast	Killed by Blast (K)	Killed by Fallout (K)	Total Killed (K)	Percent Killed	Total Survivors (K)
Adams	133.8						133.8
Allen	21.6	33	7.1		7.1	33	14.5
Ashland	122.3	1	1.2	.1	1.3	01	121.0
Ashtabula	201.9			159.9	159.9	79	42.0
Athens	145.4						145.4
Auglaize	115.4	1	1.2		1.2	01	114.2
Belmont	16.4	10	1.6		1.6	10	14.8
Brown	141.4						141.4
Butler	246.0	12	29.5		29.5	12	216.5
Carroll	112.5						112.5
Champaign	124.6						124.6
Clark	151.6	16	24.3		24.3	16	127.3
Clermont	132.1						132.1
Clinton	118.3						118.3
Columbiana	154.1			.5	.5	<1	153.6
Coshocton	162.1						162.1
Crawford	116.5						116.5
Cuyahoga	315.7	80	252.6	53.2	305.8	97	9.9
Darke	174.5						174.5
Defiance	118.9			42.1	42.1	35	76.8
Delaware	129.8	2	2.6	.2	2.8	02	127.0
Erie	77.6			9.3	9.3	12	68.3
Fairfield	145.7	1	1.5	84.1	85.6	59	60.1
Fayette	116.5						116.5
Franklin	171.9	48	82.5	13.2	95.7	56	76.2
Fulton	117.4			64.7	64.7	55	52.7
Gallia	135.9						135.9
Geauga	13.7	3	.4	13.2	13.6	99	.1
Greene	130.0	13	16.9		16.9	13	113.1
Guernsey	152.3						152.3
Hamilton	175.9	46	80.9		80.9	46	95.0
Hancock	153.5						153.5
Hardin	134.7						134.7
Harrison	107.4						107.4
Henry	120.0			32.4	32.4	27	87.6
Highland	158.4						158.4
Hocking	121.5			1.1	1.1	01	120.4
Holmes	122.3						122.3
Huron	143.4			11.5	11.5	08	131.9
Jackson	120.9						120.9
Jefferson	18.8	20	3.8		3.8	20	15.0
Knox	153.2						153.2
Lake	42.2	80	33.8	7.7	41.5	98	.7
Lawrence	11.8	33	3.9		3.9	33	7.9
Licking	197.9			90.6	90.6	46	107.3
Logan	132.7						132.7
Lorain	53.3	30	16.0	5.9	21.9	41	31.4
Lucas	95.9	40	38.4	30.2	68.6	72	27.3
Madison	133.6			.8	.8	01	132.8
Mahoning	57.9	32	18.5	21.3	39.8	69	18.1
Marion	116.8						116.8
Medina	20.4			.7	.7	03	19.7
Meigs	125.8						125.8
Mercer	128.1						128.1
Miami	117.4	15	17.6		17.6	15	99.8
Monroe	91.8						91.8
Montgomery	116.5	50	58.3		58.3	50	58.2
Morgan	79.2			.6	.6	01	78.6
Morrow	116.3						116.3
Muskingum	187.8			80.7	80.7	43	107.1
Noble	68.4						68.4
Ottawa	75.3			37.8	37.8	50	37.5
Paulding	118.8						118.8
Perry	118.3			55.1	55.1	47	63.2
Pickaway	145.4	2	2.9	14.6	17.5	12	127.9
Pike	125.4						125.4
Portage	26.4	10	2.6	23.2	25.8	98	.6
Preble	123.2						123.2
Putnam	140.2						140.2
Richland	26.0	25	6.5		6.5	25	19.5
Ross	198.2			.1	.1	<1	198.1
Sandusky	118.0			12.0	12.0	10	106.0
Scioto	175.4	2	3.5		3.5	02	171.9
Seneca	159.0						159.0
Shelby	117.7						117.7
Stark	75.4	35	26.4	6.9	33.3	44	42.1
Summit	107.0	52	55.6	42.2	97.8	91	9.2
Trumbull	49.1	37	18.2	28.5	46.7	95	2.4
Tuscarawas	164.2						164.2
Union	125.2						125.2
Van Wert	118.0						118.0
Vinton	61.8			.1	.1	<1	61.7
Warren	117.7	6	7.1		7.1	06	110.6
Washington	184.9						184.9
Wayne	161.8	2	3.2	.3	3.5	02	158.3
Williams	121.4			73.0	73.0	60	48.4
Wood	178.6	3	5.4	48.3	53.7	30	124.9
Wyandot	117.1						117.1
	10,689.2		824.0	1,066.1	1,890.1		8,799.1

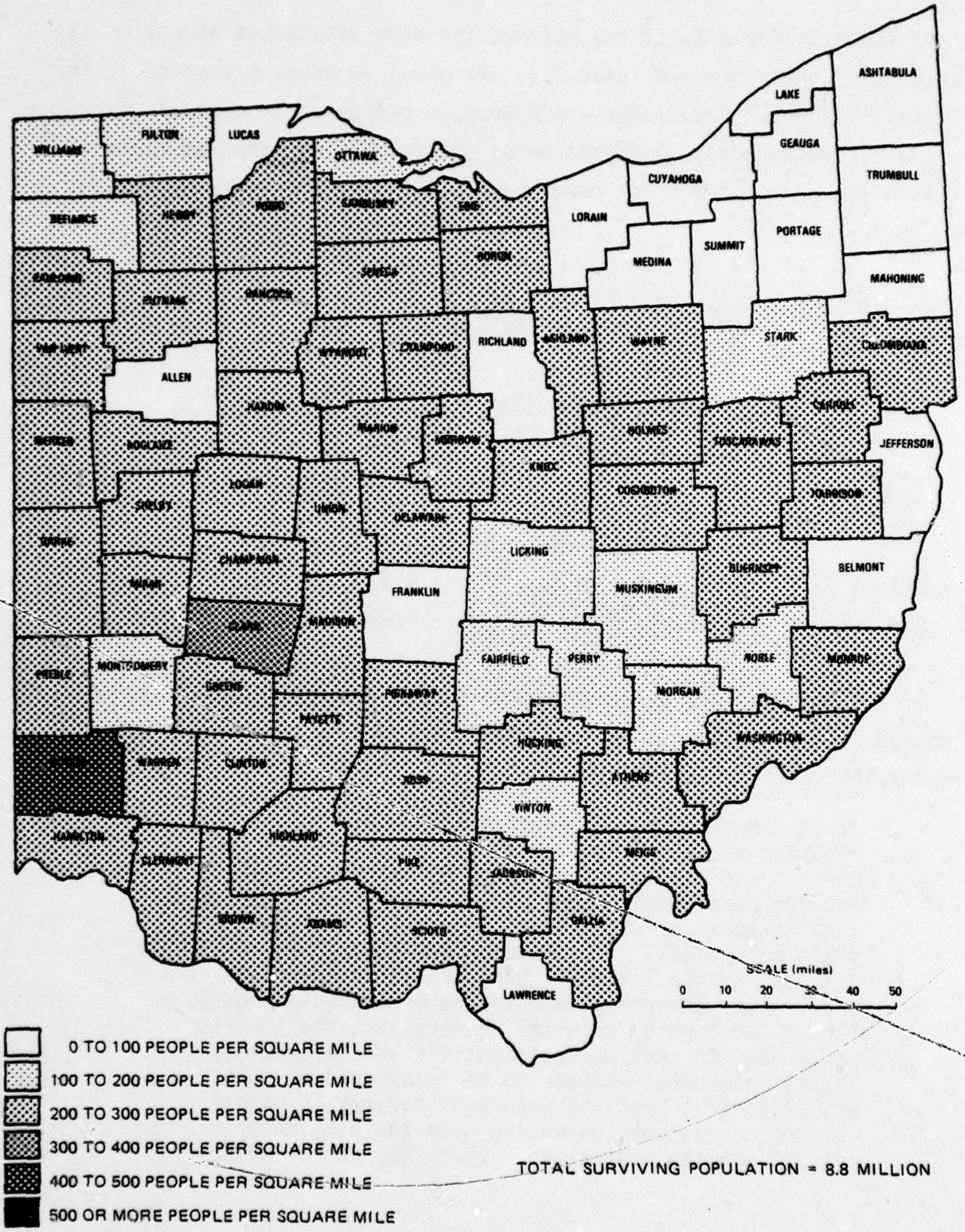


FIGURE 18. OHIO SURVIVING POPULATION DENSITY

As shown in Table 5, if one assumes the same attack but no civil defense, then *the estimated fatalities are about 82 percent instead of the estimated 18 percent fatalities under Program D-Prime. This result provides a completely independent confirmation of the results of previous analyses, for which large computer codes were used to analyze fatalities throughout CONUS.*

TABLE 5. FATALITIES IN OHIO RESULTING FROM CRP-2B ATTACK FOR VARIOUS CIVIL DEFENSE POSTURES

Initial Population = 10,700,000

	Present Case: Relocation; 2 Weeks in Shelters of PF 50	No Relocation, No Shelters; PF = 5
Killed	1,950,000 (18%)	8,820,000 (82%)
Surviving	8,750,000 (82%)	1,880,000 (18%)

If the Soviets were deliberately to target evacuees, fatalities would, of course, be much higher. However, this prospect is considered unlikely; a recent book puts it as follows:

> It is sometimes suggested that population is not regarded as an interesting target by the Soviets. This is not entirely true. The Soviets do, clearly, examine population as one element of a target set, and they do consider casualties, generally, in their decision process. . . . People per se are not considered a target by the Soviets. Only specialized aspects of a population--government administrators, people necessary to the functioning of vital centers that the Soviets would want to shut down, scientific and technically skilled personnel--appear to be considered by the Soviet General Staff as important targets to either destroy or capture, depending upon the particular mission and their location. [Ref. 20, pp. 87-88].

E. OTHER ASSUMPTIONS

Only tangible quantities, such as people, food, water, and energy, were considered in this study. It was assumed that such organizational necessities as the postattack government and economy were sufficiently effective to preserve some order and provide a reasonable distribution of available goods and services.

Postattack military requirements were also not considered. It was assumed that the war ended in such a way that the U.S. could decide for itself how to proceed next and would not be forced to follow the instructions of another nation, e.g., the U.S.S.R.

III. ENERGY

A. INTRODUCTION

This chapter examines both the various forms of energy production in Ohio and the fuel reserves normally on hand in the state. It also assesses the effect of the attack on energy supplies and future continued production after the attack. Section B addresses preattack fuel reserves. Section C considers preattack production of energy; i.e., coal mining, electrical power generation, crude oil production, and petroleum refining. In Section D, attack damage to energy reserves and production capacity is discussed, and conclusions are drawn in Section E.

B. PREATTACK FUEL SUPPLIES IN OHIO

As a consequence of the disruption of crude oil production, petroleum refining, coal mining, and electrical power generation in the aftermath of an attack, undamaged fuel supplies would constitute the primary source of energy in the first postattack year. Specifically, surviving gasoline and diesel fuel in stock would be of the greatest importance because of their role in both the production and transportation of food.

Gasoline and diesel fuel supplies are located at several types of facilities in Ohio. Table 6A lists the stocks at these facilities. The largest quantities of these fuels are in the bulk storage facilities. Data on the distribution of fuel supplies in bulk storage in Ohio is not readily available; therefore, the size of this source of stored fuel had to be estimated. The U.S. Department of Energy provided monthly figures for statewide bulk gasoline and distillate fuel oil stocks in Ohio during 1978 [Ref. 21]. (It is assumed that under postattack emergency conditions, all distillates, including diesel oil, could be used as motor fuel.) The

TABLE 6. FUEL STOCKS IN OHIO

A. PREATTACK FUEL STOCKS IN OHIO

Location	Gasoline (gal)	Diesel Fuel and Other Distillates (gal)
Bulk storage	192,000,000	146,000,000
Retail dealers (service stations and truck stops)	76,000,000	1,000,000
Farms	25,000,000	25,000,000
Total	293,000,000	172,000,000

B. POSTATTACK FUEL STOCKS IN OHIO

Location	Gasoline (gal)	Diesel Fuel and Other Distillates (gal)
Bulk storage	56,400,000	52,500,000
Retail dealers (service stations and truck stops)	28,500,000	560,000
Farms	25,000,000	25,000,000
Total	110,000,000	78,100,000
Percent of preattack stocks	38	46

size of gasoline and distillate fuel oil stocks for an average month was calculated. The statewide average for gasoline was 192 million gallons, and the average for diesel was 146 million gallons. Using Bureau of the Census data [Ref. 22], these average month aggregates were then distributed among the counties in Ohio in proportion to the bulk storage capacity in each county [Ref. 23]. These data are shown in Figure 19.

The next largest portion of fuels can be found at the retail dealer establishments; i.e., gasoline service stations and truck stops. The average gasoline station in Ohio has approximately 8,500 gallons of gasoline in hand at any time [Ref. 24], and there are approximately 9,000 stations operating in Ohio [Ref. 24]. While the average fuel on hand at truck stops is somewhat higher, about 11,000 gallons, than for gasoline service stations [Ref. 24], the number of these stations, roughly 90 in Ohio [Ref. 25], is low enough so that, in the aggregate, they contain only about 1,000,000 gallons of diesel fuel.

Fuel is also stored on farms in Ohio. It is estimated that well over 90 percent of the farms in the state have some fuel storage capacity [Ref. 24]. This fuel is significant not only because of its quantity, but also because of its dispersion and relative safety from attack. Generally, the amount in storage is about 500 gallons [Ref. 24], with some seasonal variation. This amounts to a total of 50,000,000 gallons of fuel for the approximately 110,000 farms in Ohio. This total is split approximately evenly between diesel fuel and gasoline [Ref. 26].

In sum, the total significant preattack fuel stocks in Ohio at any one time are approximately 300 million gallons of gasoline and 180 million gallons of diesel fuel and other distillate fuel oils.

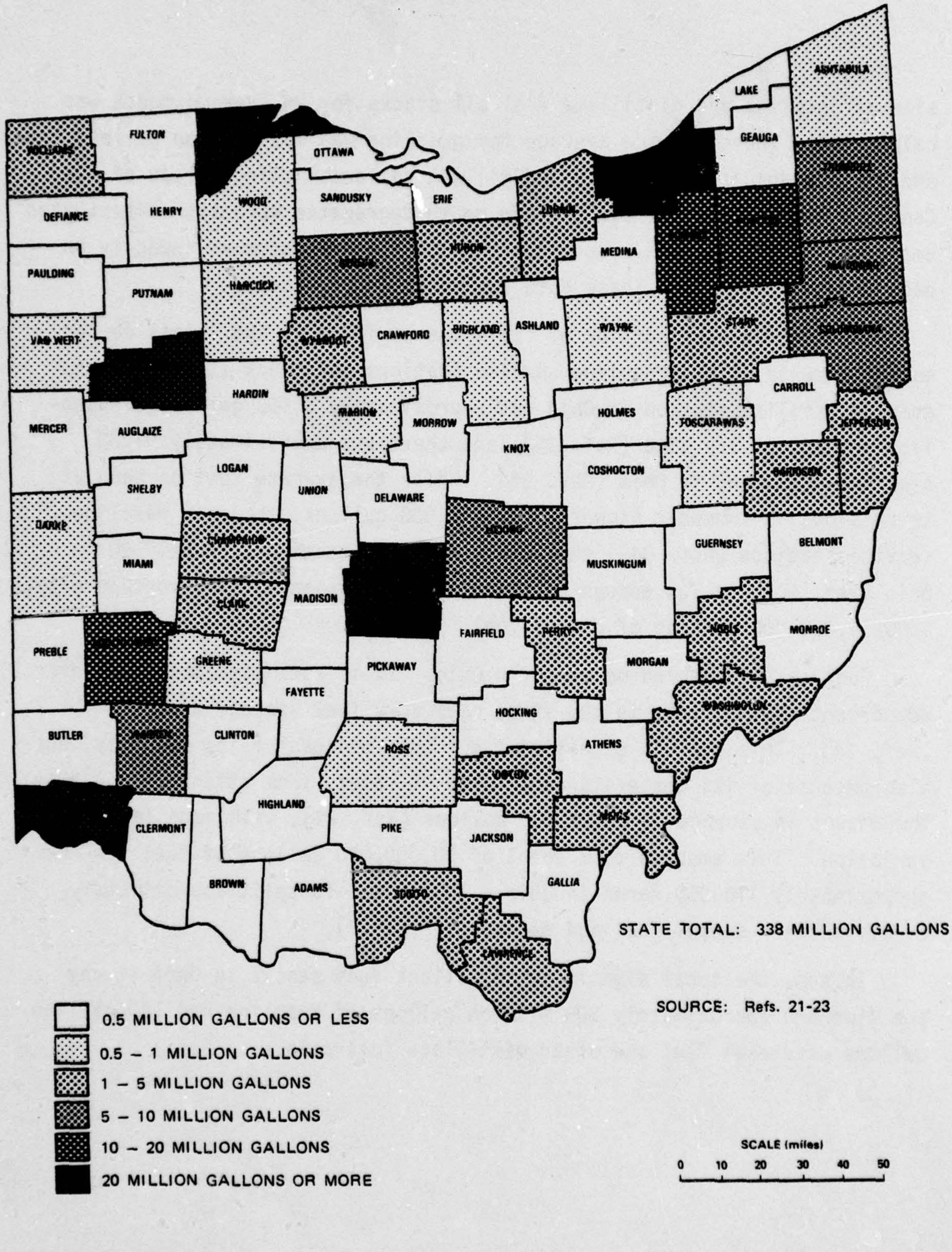


FIGURE 19. ESTIMATED FUELS IN BULK STORAGE FACILITIES (Gasoline and Diesel Fuel)

C. CURRENT ENERGY PRODUCTION IN OHIO

1. Petroleum

Ohio is the 19th ranked state in terms of crude oil production in the U.S. Its daily production is about 30,000 barrels, spread among 17,000 wells [Ref. 27]. These wells are primarily "stripper" wells; i.e., individually, they produce small amounts of crude. Most of this crude oil is refined outside of Ohio [Ref. 27].

Ohio has significant capacity for refining oil. However, almost all of the crude oil refined in Ohio comes from out-of-state sources [Ref. 28]. Figure 20 shows the capacity for refining crude oil, in terms of barrels of crude oil per day. Figure 21 shows Ohio's capacity for production of gasoline, also in barrels/day. As can be seen in these maps, Ohio's oil refining capacity is confined to five counties and a total of seven refineries, one of which is operable but presently shut down [Refs. 29, 30].

2. Coal

Production of coal in Ohio is approximately 45 million net tons annually. Coal production is detailed by county in Figure 22. Most of the coal in Ohio is produced in underground mines as opposed to surface or strip mines [Ref. 28].

The primary use for coal in Ohio is electrical power generation. Approximately the same amount of coal, 45 million net tons, is consumed annually for this purpose as is produced in the state [Ref. 28]. However, normally Ohio exports about 12 million tons of coal while importing about 37 million tons. The excess imported coal is consumed in other industries; e.g., steel production [Ref. 28].

3. Electrical Power Generation

Approximately 80 million megawatt hours of electricity are generated annually in Ohio [Ref. 28]. The distribution of electrical power generation on a county-level basis is depicted in Figure 23. The electric power grid is shown in Figure 24. In Ohio, 96 percent of all electric power

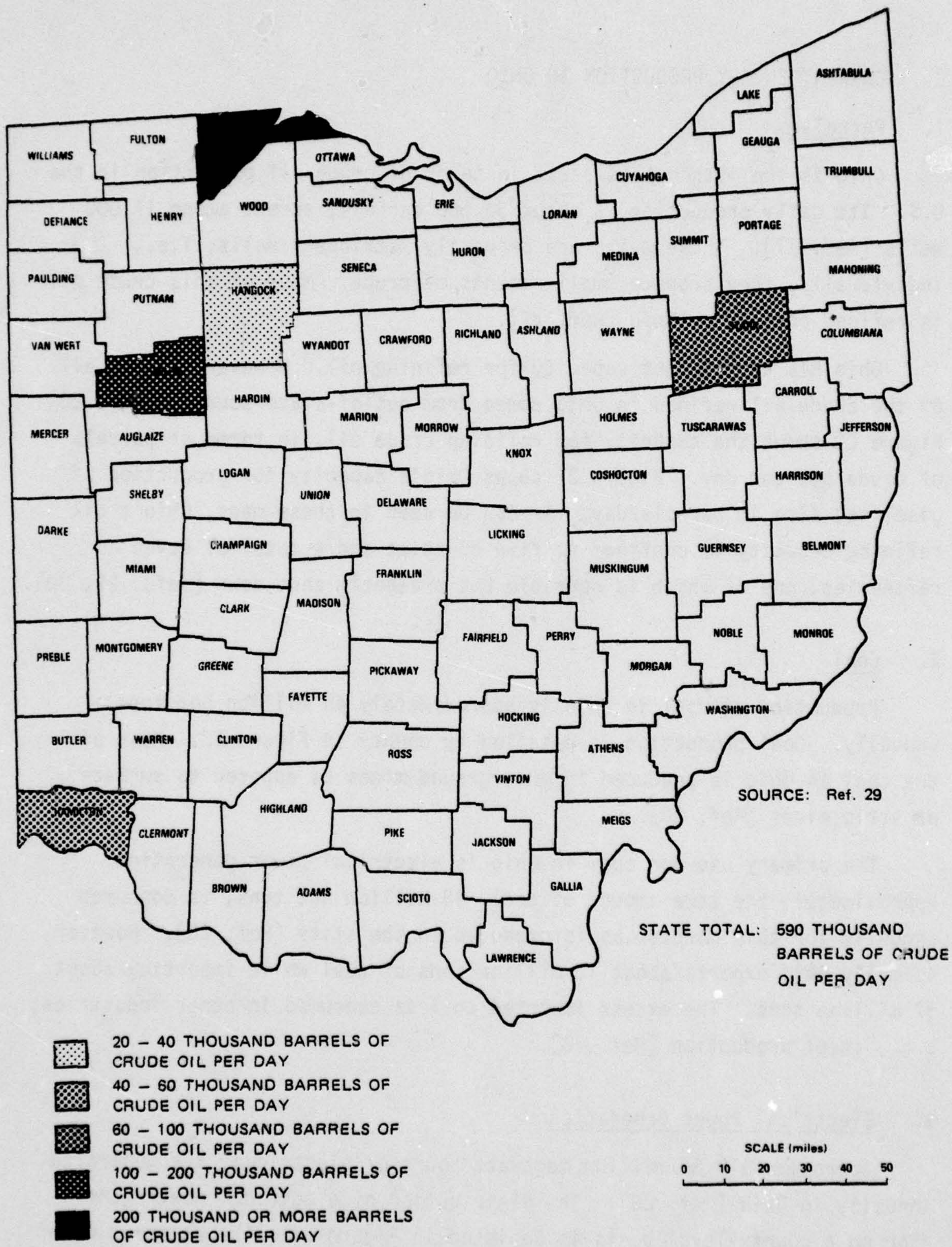
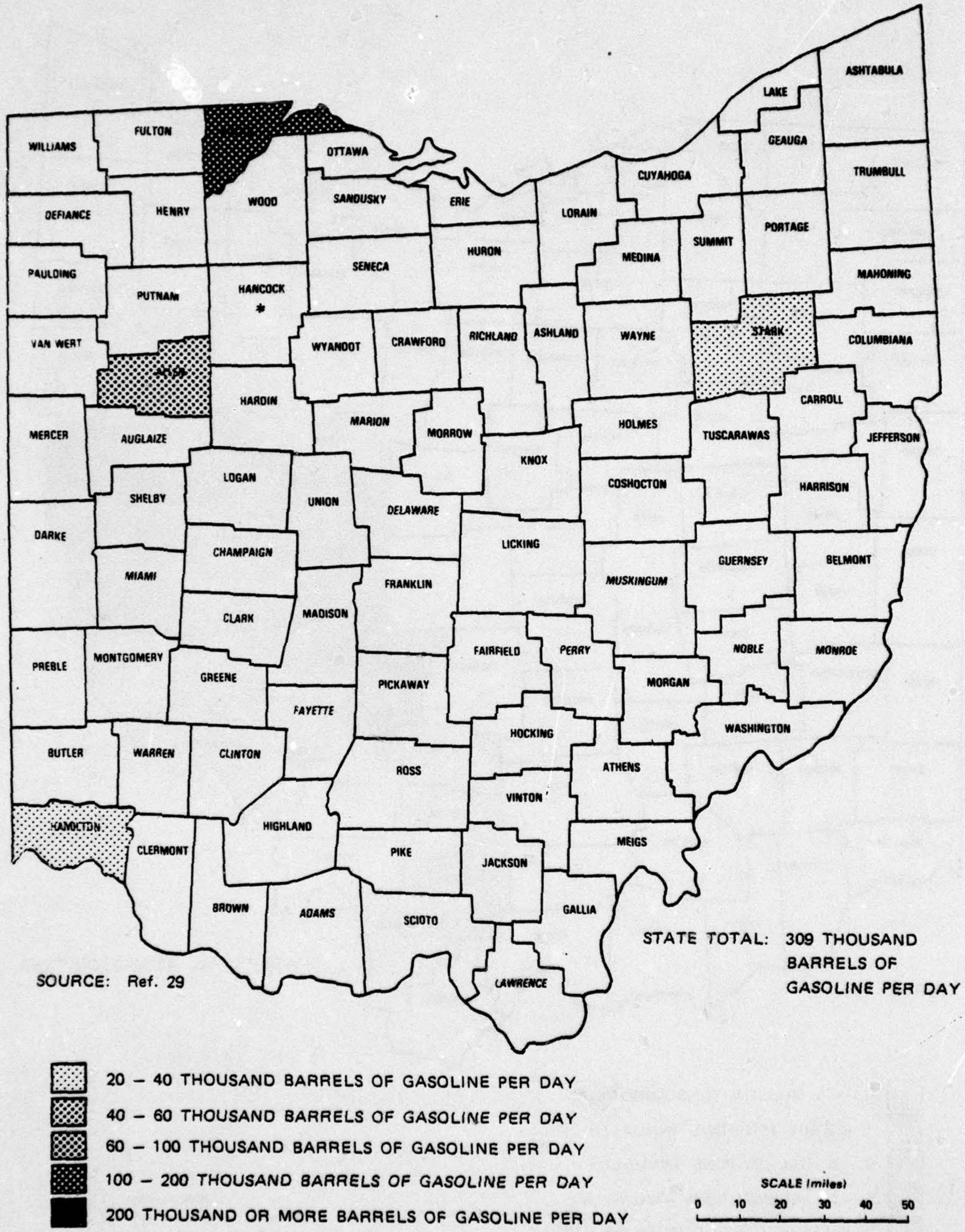


FIGURE 20. OHIO OIL REFINERY CAPACITY – INPUT



* THE REFINERY IN HANCOCK COUNTY ONLY PRODUCES ASPHALT, DIESEL FUEL, HEAVY FUEL OIL AND JET FUEL.

FIGURE 21. OHIO OIL REFINERY CAPACITY – OUTPUT

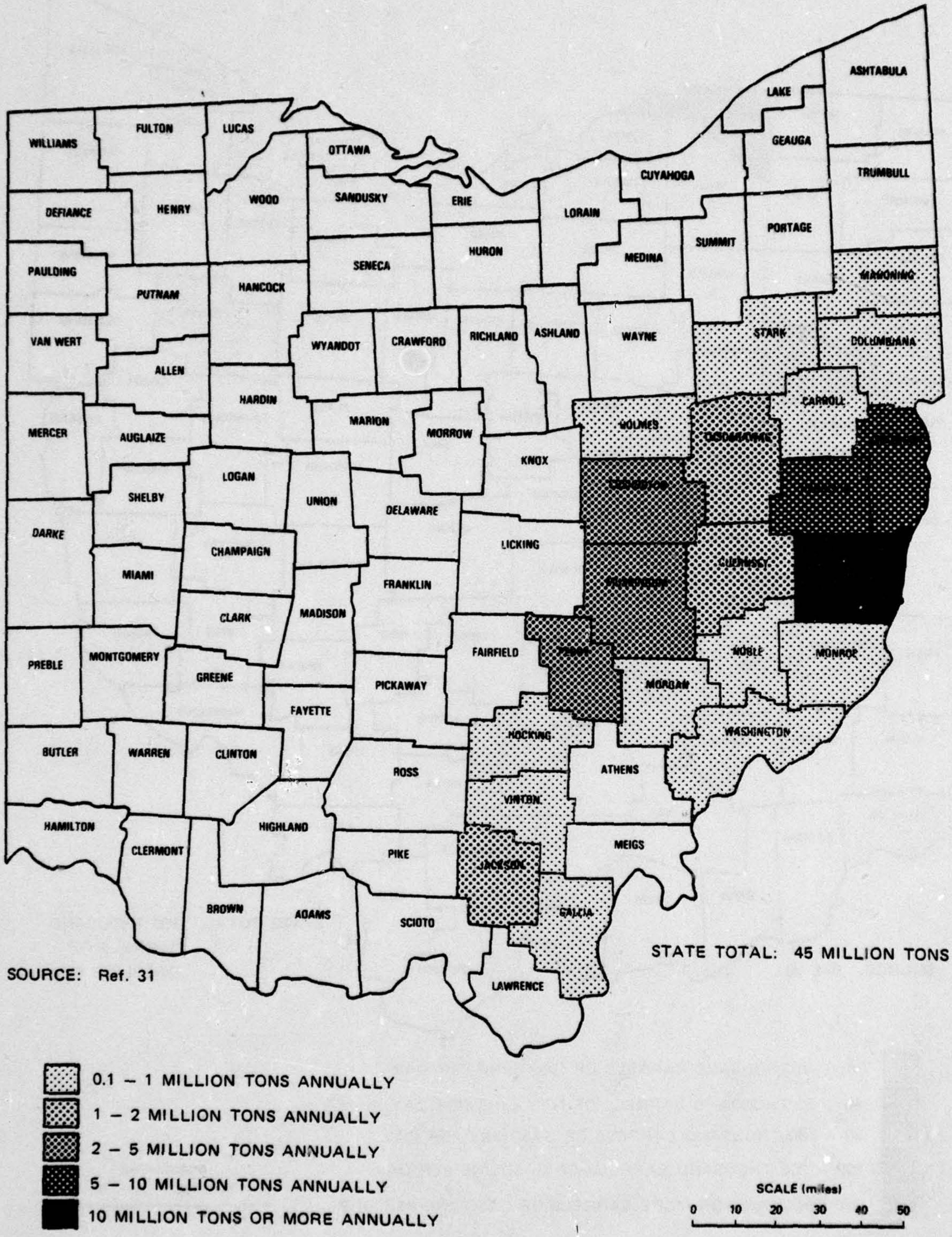


FIGURE 22. COAL PRODUCTION IN OHIO

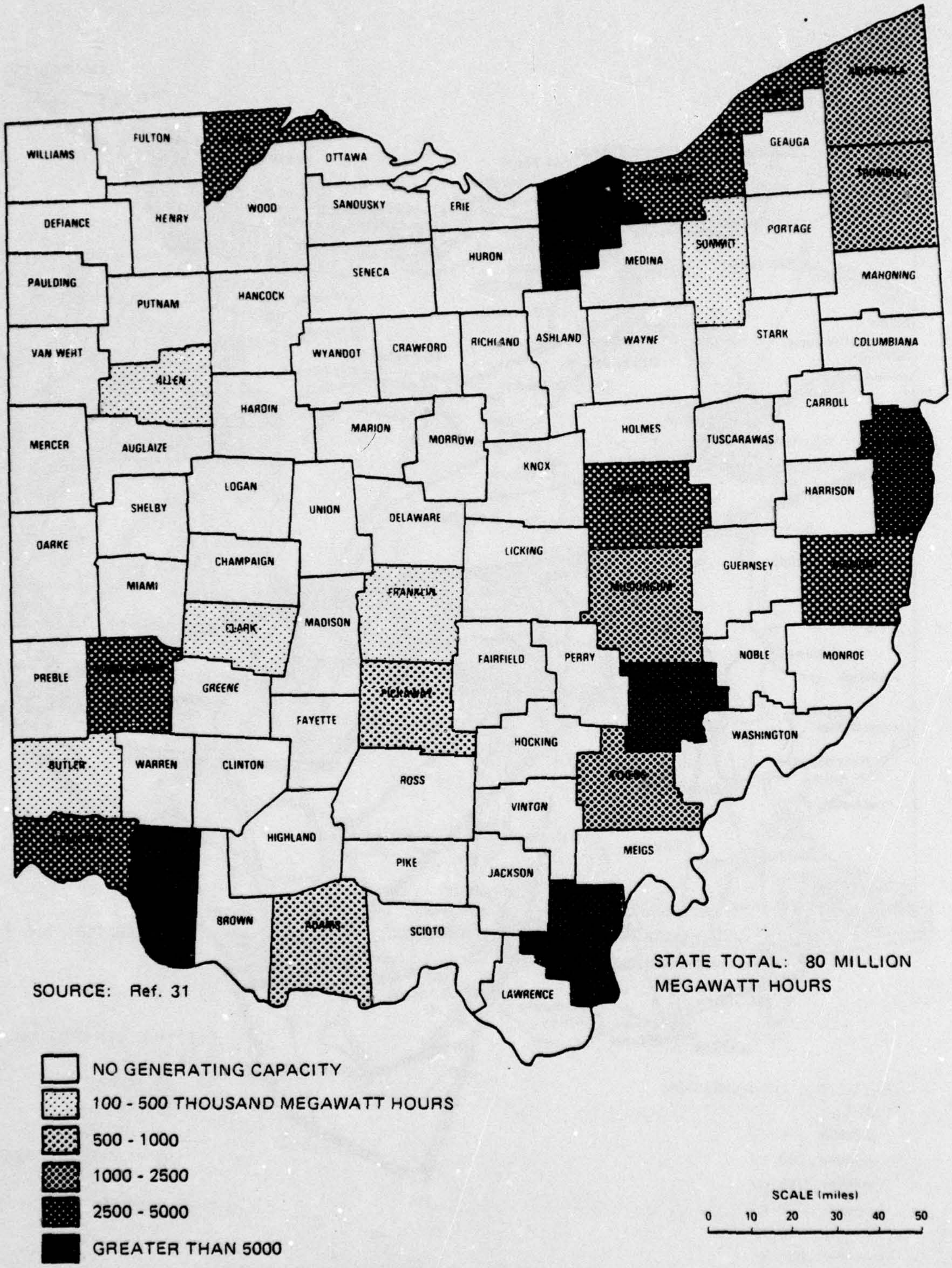
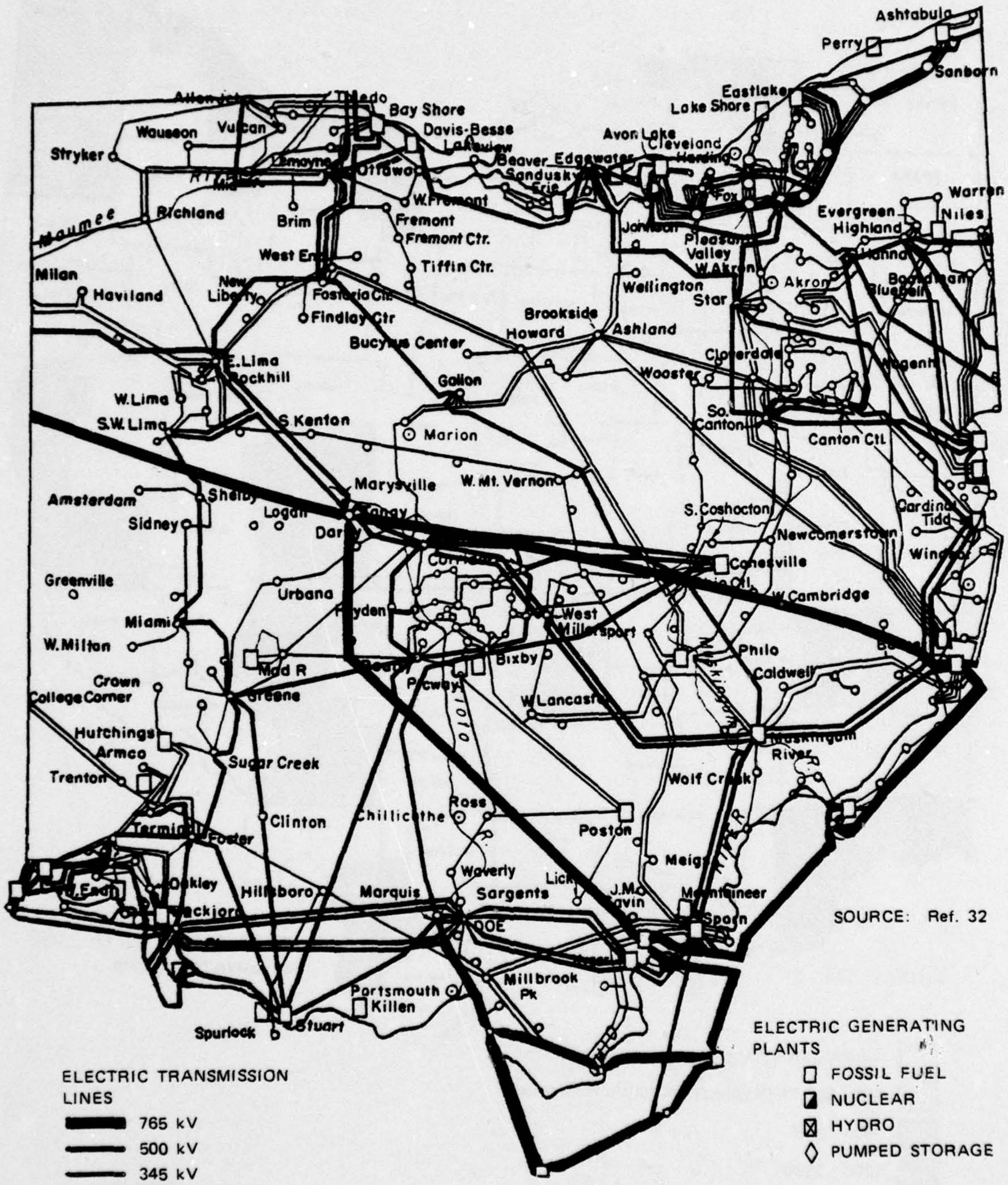


FIGURE 23. OHIO ANNUAL ELECTRICAL POWER GENERATION



SOURCE: Ref. 32

ELECTRIC TRANSMISSION LINES
765 kV
500 kV
345 kV
230 kV
100-161 kV
69 kV

ELECTRIC GENERATING PLANTS
FOSSIL FUEL
NUCLEAR
HYDRO
PUMPED STORAGE

TRANSMISSION STATIONS

FIGURE 24. OHIO ELECTRIC POWER GRID

generation is coal fueled [Ref. 28]. As noted above, consumption of coal for production of electricity is approximately 45 million tons per year.

D. POSTATTACK ENERGY

Before considering the effects of the attack on fuel in storage, the consequences of a relocation of the at-risk population of Ohio, primarily by automobile, should be taken into account. The typical distance that evacuees will have to travel to reach their host counties is somewhat less than 100 miles. Because the average relocation distance is relatively short, little refueling along the way will be necessary. Assuming that the average car presently gets about 15 miles per gallon, the average amount of gasoline required will be roughly 7 gallons. However, cars generally have at least a few gallons in the tank, so that the amount required for relocation would be correspondingly reduced.

The number of cars estimated to relocate with the population out of risk areas is 3,350,000. In these same risk areas, the total available gasoline at service stations is 48 million gallons [Ref. 24, 33]. This is more than 14 gallons per car, or twice what would be needed to relocate, even if cars were assumed to have no gasoline in their tanks. Thus, consumption of gasoline during the relocation will not have a significant impact on postattack supplies, since all of the required gasoline can be supplied from service stations in the areas at risk. Furthermore, most of these fuel stocks would be lost to the attack if left in place.

The destruction caused by the attack to both fuel supplies in storage and production and refining facilities is severe. Table 6B, which parallels the information provided in Table 6A, indicates the surviving supplies. As a consequence of the concentration of bulk storage facilities in risk areas, only about 30 percent of these stocks survive. This damage assessment assumes complete destruction of storage facilities inside 5-psi blast overpressure contours [Refs. 16, 34, 35]. Using the same damage criterion, approximately 38 percent of the stocks at retail dealer

establishments survive. Only the fuels on hand on farms survive the attack without significant damage. The total fuel in storage in Ohio after the attack is approximately 110 million gallons of gosoline and 78,000 gallons of diesel fuel and other distillates.

These remaining fuel stocks will be of extreme importance in the first year following the attack because the damage done to the petroleum refineries in Ohio makes continued production in the first postattack year highly uncertain [Ref. 36]. Of the seven refineries in Ohio, six are destroyed, again using 5 psi as the lethal blast overpressure. The remaining facility is a small one in Hancock County with a capacity of 20,400 barrels of crude oil per calendar day [Ref. 29]. The Hancock refinery is operated only on a seasonal basis. It has no capacity to produce gasoline, but does produce some diesel fuel [Ref. 30]. As a result of the relative dispersal of Ohio's 17,000 oil wells, it is expected that they would mostly survive, and might be able to supply this one facility with crude oil. Whether limited refining and production would be possible would also depend on other variables such as transportation for the oil and the availability of electricity.

The problem of continued coal production would be similar to that of crude oil production. The mines, like the wells, would not be damaged directly by the attack. However, the mines, which are of the underground type, would need electricity to operate.

Electrical generating capacity also is heavily damaged by the attack. Roughly 40 percent of generating capacity survives undamaged. However, severe damage to the power grid might make transmission of the power to areas where it would be needed problematic. Clearly, some local regions would have power. Coal-fired central stations tend to maintain roughly 80 to 100 days' normal supply [Ref. 35]. Given drastically reduced demand for electricity, on-site fuel supplies could probably be stretched until some production and distribution of coal could be resumed. It should be noted that the TR-82 attack does not assume direct targeting of power plants. However, FEMA officials believe Soviet targeting of the electrical power network is likely, and such an attack pattern will probably be incorporated in future hypothetical attacks used by the agency.

E. SUMMARY

In the initial aftermath of the attack, fuel reserves in Ohio would be about 110,000,000 gallons of gasoline and 78,000,000 gallons of diesel and other distillate fuels. These fuels would be critical to the preeminent survival needs of food production and food transportation, and their use would have to be severely restricted to these purposes. Some petroleum refining capacity might survive, but it would be a small fraction of the preattack capacity and would similarly need to be carefully allocated to critical tasks.

IV. TRANSPORTATION

A. ROAD TRANSPORTATION

Figure 25 is a map of major roads in Ohio. The majority of the road network, especially minor roads, survives the postulated attack. In fact, a road must essentially be cratered in order to be destroyed. Thus, even in heavily damaged areas, many roads will remain undamaged except for being strewn with rubble.

During the first year postattack, fuel will be at a premium. Transportation by private automobiles will surely be a luxury, perhaps limited to emergencies and other highly specialized uses. For this study, it was assumed not to take place.

The number of bicycles per capita in the U.S. today is about 0.4 [Ref. 37]. (Specific data for Ohio were not available). For moving a given weight a given distance, a bicycle is several times as energy-efficient as any other mode of transportation [Ref. 38]. Evacuees should be encouraged to bring their bicycles with them, if possible, to use for individual short-trip transportation after the attack.

Road transportation of goods between counties can be done by truck. Table 7 gives some data regarding trucks. For this study, it was estimated that about 60 percent of Ohio's trucks would survive the attack. The fraction surviving was estimated to be somewhat less than the fraction of people surviving, since a disproportionate fraction of trucks were assumed to be in the urban areas--participating in the food distribution to evacuees--when the attack occurred.

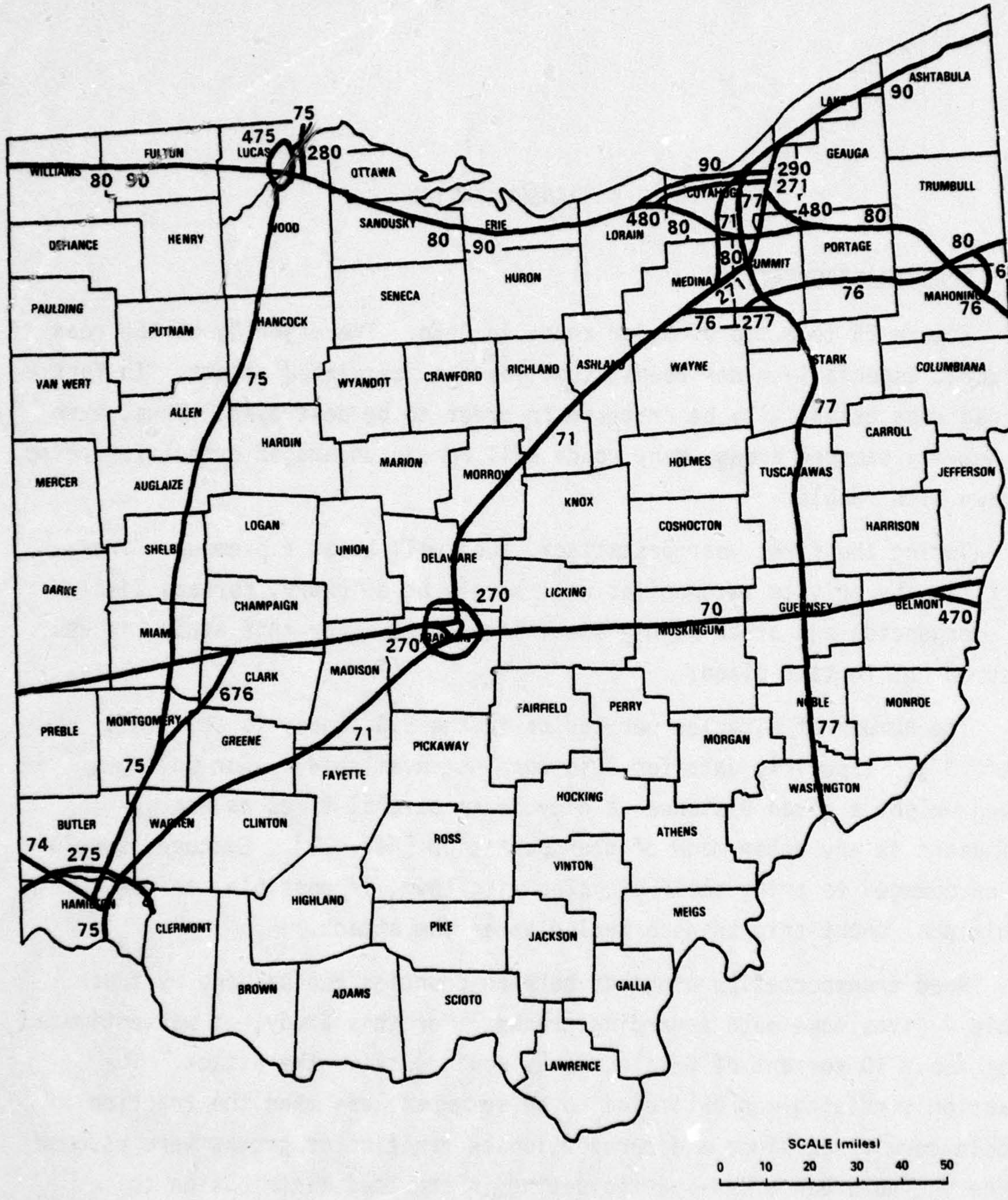


FIGURE 25. OHIO MAJOR HIGHWAYS

TABLE 7. OHIO TRUCKS

Number of trucks registered in Ohio (1976) =	625,000 [Ref. 39]
Estimated number of trucks surviving the attack (60 percent):	375,000
Estimated capacity of large truck:	Volume: 14 m^3 Weight: 11 tons (@ 2,000 lb)
Typical truck mileage:	8 miles/gallon [Ref. 40, p. 164]
Estimated carrying capacity:	~50 ton-miles/gallon

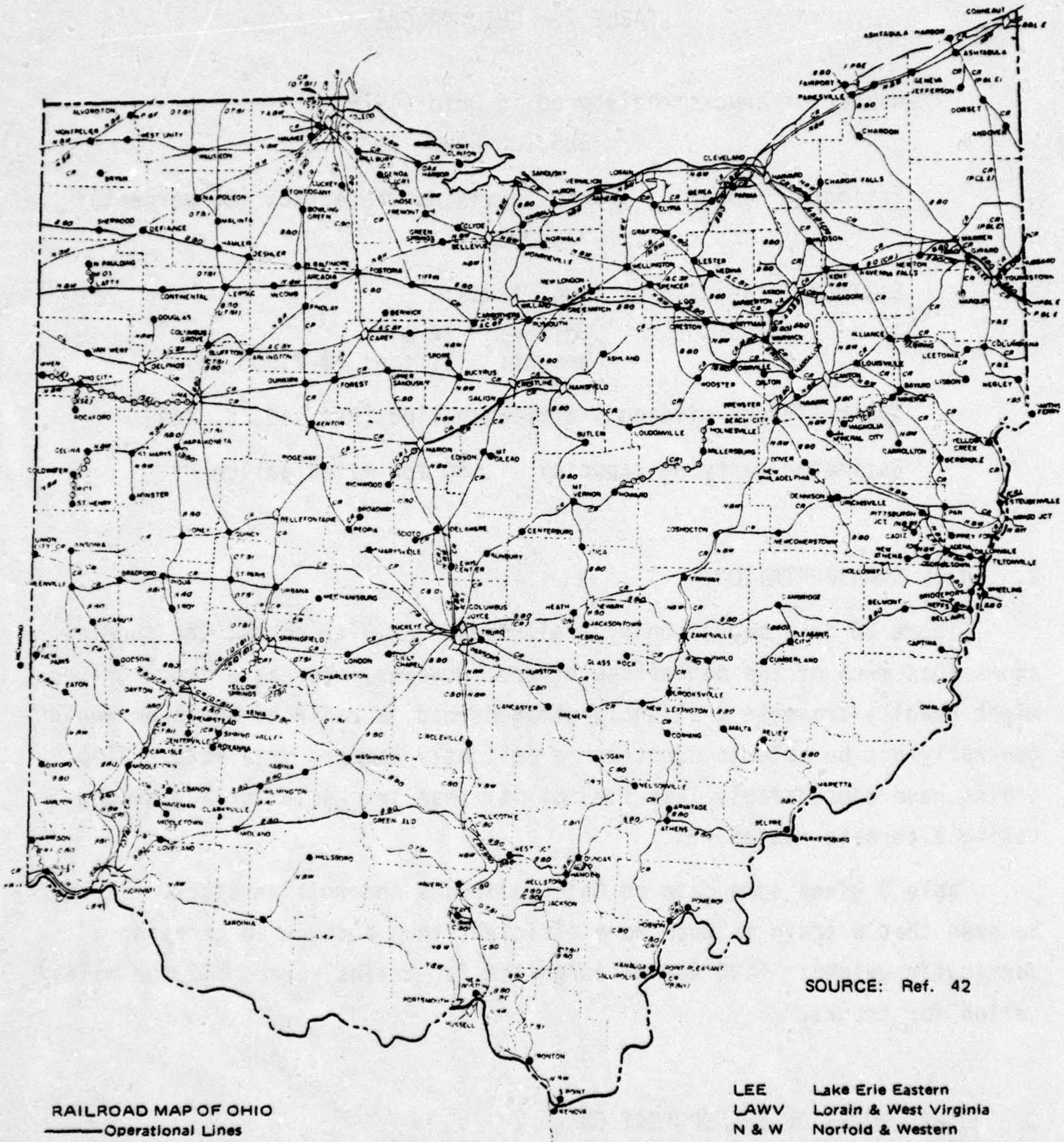
B. RAIL TRANSPORTATION

Figure 26 is a map of Ohio's railroads. As with roads, the overlay shows that much of the network survives. However, whereas a truck driver might readily traverse a slightly damaged road, a railroad engineer would generally not be able to negotiate a "slightly damaged" railroad. Also, trains have considerably less flexibility than trucks in turning around, taking alternate routes, etc.

Table 8 gives some data on Ohio railroads and rolling stock. It may be seen that a train is much more efficient than a truck in carrying a particular weight: ~190 ton-miles/gallon for trains versus ~50 ton-miles/gallon for trucks.

C. OTHER MODES OF TRANSPORTATION

Figure 27 is a 1968 map of Ohio airports [Ref. 41]. Although the largest airports are destroyed by the attack, almost every county has a small airport. Thus, a minimal amount of air transportation, using small planes, would probably be possible during the first postattack year.



SOURCE: Ref. 42

RAILROAD MAP OF OHIO

- Operational Lines
- Operational Lines Under Subsidy
- RR Owner Operator
- (RR) Operator with Lease Agreement or Trackage Rights
- Rail Yard

A & BB	Akron and Barberton Belt
AC & Y	Akron, Canton, and Youngstown
B & O	Baltimore and Ohio
CR	Conrail
DT & I	Detroit, Toledo, and Ironton
F, P, & E	Fairport, Painesville and Eastern
LEE	Lake Erie Eastern
LAWV	Lorain & West Virginia
N & W	Norfold & Western
P & LE	Pittsburg & Lake Erie
P & F	Pioneer & Fayette
SE	Spencerville Eglin
TA & W	Toledo, Angola & Western
TT	Toledo Terminal
WO	Western Ohio
Y & S	Youngstown & Southern

FIGURE 26. OHIO RAILROADS

However, because of the fuel inefficiency of air travel and the limited amount of fuel available postattack, air transportation will presumably be limited to extremely specialized uses.

Transportation by water was not addressed in this study. However, it is quite efficient and could probably play a role in the postattack period.

TABLE 8. OHIO RAILROADS AND ROLLING STOCK

Number of all types of freight cars: ∿40,000 (majority [∿40 to 50 percent] would be box cars)

Number of Locomotives: ∿3,500

Amount of regular track:	∿7,600 miles
Switching and transfer track:	∿ 400 "
	∿8,000 "

Capacity of cars (transition now under way from old to new):

Freight cars: Old: ∿64 tons
New: ∿90 tons

Grain cars: Old: ∿2,000 bushels
New: (∿75%): ∿3,800 bushels

Maximum train length: Is limited by number of curves in track. A "big" train is considered to be ∿100 to 150 cars (would require ∿2 locomotives)

Locomotive fuel consumption: = 190 ton-miles/gallon diesel fuel
= 0.0053 gallon diesel fuel/ton-mile
= 740,000 joules/ton-mile

Source: Reference 42.

D. SUMMARY

Most trucks would survive the attack, as would roads in all rural parts of the state. Transportation of goods during the first year could apparently be accomplished if enough fuel were available.

★ AIRPORTS SERVED BY MAJOR AIRLINES

/ EXISTING RUNWAYS, 3000 FEET OR MORE

● RUNWAYS UNDER CONSTRUCTION OR PLANNED, 3000 FEET OR MORE

FIGURE 27. OHIO AVIATION FACILITIES, 1968

V. FOOD

This chapter examines the availability and adequacy of food supplies in Ohio in the first year following a large-scale nuclear attack. In the first section, important aspects of the postattack diet are detailed. The second section analyzes the size of stored food stocks in the state that are undamaged by the attack. As these stocks were exhausted, the resumption of agricultural activities would become an increasingly critical postattack task. Therefore, the final section of this chapter considers the problems likely to affect postattack agriculture.

A. THE POSTATTACK DIET

1. Postattack Need for an Adequate Diet

Perhaps the single most vital task of the first year would be the provision of an adequate supply of food for the surviving population. The importance of maintaining a sufficient postattack diet is discussed in detail below.

a. To Promote the Good Health of the Initial Survivors

Malnutrition lowers the body's resistance to infectious diseases and inhibits a person's ability to recover from an illness. Furthermore, extremely restricted Caloric intake over extended periods can cause irreversible damage to body tissues [Ref. 43]. Prevention of dietary deficiency, then, would be important if other likely postattack health problems (e.g., radiation sickness) are not to be exacerbated.

b. To Support Worker Productivity

Postattack survival and recovery activity would be labor intensive and require at least moderate, and most likely arduous, physical work. Although limits on food intake may be possible in the short term, restricted diets would eventually begin to impede recovery. A study of the effects of rationing on the output of German construction workers, coal miners, and steel workers during World War II found that:

> ...every professional activity requires a fixed amount of calories. No activity can be continuously greater than in accordance with the caloric intake; otherwise loss of weight is induced, and this lowers the capacity, finally stopping work entirely.
>
> ...Our results prove that rationing of food also means rationing of industrial production of a country.... Reconstruction is a problem of calories [Ref. 44].

Inadequate diet may even constrain food production itself, thereby creating a "subsistence loop"; i.e., a situation where food shortages result in deficient diets for workers, which result in low worker productivity. Low worker productivity, in turn, reduces food production, further diminishing the food supply, and so on [Ref. 2].

In addition to reductions in work output caused by malnutrition *per se*, a decline in postattack worker productivity may occur because of absenteeism induced by a need for workers to hunt for their own food. Again, experience during World War II supports this conclusion:

> ...maintenance of a sufficient food supply in a bombed city is more decisive for the efficient functioning of manpower than any other type of resource. A plentiful food supply, more readily obtainable within the city than outside is one of the most effective incentives for workers to remain in a partially damaged city in spite of other deprivations and the danger of future attacks. This was an important factor in the remarkable recuperation of Hamburg. On the other hand, authorities will hardly be able to keep essential workers in a bombed city if the supply of food is not sufficient. During the later years of World War II, food became so scarce in German cities that workers

> resorted to week-end trips to the country to round out their food rations through purchases or foraging in farm areas. This caused absenteeism.... The food scarcity in Japanese cities was generally worse than in German cities. It is reported from Kobe that day laborers, badly needed in the war industries, fled to the country after the heavy raids because of food shortages in the city [Ref. 45].[1]

In sum, an adequate postattack diet is required to support the degree of worker productivity necessary for the difficult work of the survival and reorganization phases. Although further elaboration will not be provided here, the link between food intake and work output raises difficult questions for postattack planning that center on the tradeoffs between equity and efficiency resulting from alternative rationing schemes.

c. To Prevent Social Disorder

Even though food consumption may be sufficient in strictly physiological terms, postattack social unrest may be evident in a population (like that in the United States) that is accustomed to a standard of living far above subsistence [Ref. 2]. Food shortages or monotonous and unpalatable diets can be causes of unproductive individual behavior, declining morale, and diminished social cohesion, which, in turn, would work against recovery efforts. Analyses of the effects of World War II strategic bombing on Germany and Japan indicate that:

> ...in some [German] working class areas food shortages may have been "the last straw" leading to overt threats of refusal to work. This observation is in accord with other reports on the effects of severe food shortages. It is this type of deprivation which seems to have the

[1]Given the (1) destructive power of nuclear weapons, (2) the likely massive destruction of urban centers in any large-scale nuclear attack, (3) FEMA's current planning emphasis on crisis relocation, and (4) the nature of the economic activities in the initial recovery period, the problem after a nuclear attack, unlike World War II, will not be to keep the workers in what remains of the cities. Nonetheless, the World War II experience does clearly demonstrate the need for sufficient provision of food to maintain an organized labor force.

greatest potential for fulminating overt rebellion and countermores behavior. Food shortages have been emphasized as an important factor in the deterioration of behavioral morale among Japanese civilians [Ref. 46].

In sum, it is important to begin with a statement of broad requirements because (1) they point to the criticality of the food supply to the progress of economic and social recovery, and therefore (2) establish limits on the extent to which diets can be reduced (if any such flexibility is possible).

2. Defining an "Adequate" Postattack Diet

The postattack demand for food would be determined by the size of the surviving population and their per capita nutritional requirements. Detailed analysis shows that dietary requirements vary between different groups as well as within the same group. Degree of physical activity, body size, age, and sex are important factors affecting nutritional needs. However, if one adopts a postattack perspective, these differences become relatively small, and, for planning purposes, dietary requirements can be defined in broad brush; i.e., using simple averages for the entire population. Moreover, given the multitude of uncertainties inherent in predictions concerning the postattack environment, precise definition of the nutritional needs of subgroups in the population seems incongruous and unnecessary. Therefore, an "adequate" postattack diet is defined in general terms.

a. Calories

The most compelling postattack dietary need will be for Calories or food energy. As one study has noted, "Calorie sufficiency surely does not guarantee postattack health for all, but Calorie deficiency insures ill health for many." [Ref. 47]

A report prepared by a panel of nutritionists for the Food and Agriculture Organization has estimated the food energy requirements of a "reference man" and a "reference woman" to be 3,000 Calories/day and 2,200

Calories/day, respectively [Ref. 48].[1] The N.A.S.-N.R.C. Food and Nutrition Board in its most recent calculation of recommended daily dietary allowances ("designed for the maintenance of good nutrition in practically all healthy people in the U.S.A.") indicates a range of needed food energy from 1,300 Calories for very young children to 3,000 Calories for young adult males [Ref. 49].

Even when compared with the above standards, the current average American daily intake of Calories is luxurious. In 1977, about 3,380 Calories/person-day were consumed. Moreover, since the beginning of this century, the number of Calories in the U.S. diet per capita per day has never fallen below 3,100 [Ref. 50]. Clearly, there would be room for compression in the Caloric intake of the postattack population. The question is--How much room?

A variety of estimates of postattack Caloric requirements exists. At the one extreme, man can survive starvation for up to 60 days or more, although irreversible damage to body tissues is likely to occur [Ref. 43]. Shelter occupants might be able to subsist on as little as 800 Calories/person-day [Ref. 51]. M.I.T. nutritionists Miller and Scrimshaw estimate that in the first month or so postattack, 1,200 to 1,500 Calories/person-day should maintain normal healthy individuals (excluding children under 4 years of age and pregnant and lactating women, who have higher Caloric requirements) [Ref. 52].

---

[1]The reference man "is between 20 to 39 years of age and weighs 65 kg. He is healthy, that is, free from disease and physically active for work. On each working day he is employed for 8 hours in an occupation that usually involves moderate activity. When not at work, he spends 8 hours in bed, 4 to 6 hours sitting or moving around in only very light activity, and 2 hours in walking, in active recreation, or in household duties." The reference woman is similar to the reference man, differing only in her weight (55 kg) and physical activity. ("She may be engaged for 8 hours in general household work, in light industry, or in other moderately active work.")

The first year after a nuclear attack, however, would probably involve a fairly high degree of physical work by the population. Therefore, a daily per capita food energy intake falling in the range of 800 to 1,500 Calories will probably prove inadequate. The Department of Agriculture's National Emergency Food Consumption Standard "establishes a maximum level for consumer food rationing and mass feeding operations during the immediate [unspecified] postattack period of between 2,000 and 2,500 Calories per person per day" which is claimed to be sufficient "to maintain a reasonable degree of health and vigor for a limited [unspecified] time." [Ref. 53] These figures bracket the 2,175 Calories/person-day ration used by Bernard Sobin in his study of the first one or two postattack years [Ref. 4]. A recent report of the Joint Committee on Defense Production argues that an average of 2,700 Calories/person-day would be needed, assuming moderate postattack activity [Ref. 54]. Rather than attempting to reconcile these different assessments of the postattack Caloric requirement, 2,500 Calories/person-day was selected as an appropriate food energy criterion. For planning purposes, 2,500 Calories/person-day should be above subsistence when averaged over the entire population, and at the same time take into account the higher intakes needed for those engaged in strenuous recovery activities.

b. Protein

After food energy, protein is the next most important category of nutritional need. Protein is required for tissue growth, development, and replacement. It should be noted that Caloric and protein intakes are related such that, when Caloric deficiency occurs, available protein is not utilized effectively, some of the protein being used to fulfill energy rather than protein needs [Ref. 48].

Pogrund has estimated the minimal daily protein requirement to be 0.3 to 0.35 grams/kilogram of body weight if animal protein is consumed and 0.5 to 1.0 grams if the protein source is plants [Ref. 43]. The "reference man's" protein requirement would then be 20 to 23 grams (animal protein)

or 32 to 65 grams (plant protein), and the "reference woman's" need would be 16 to 19 grams (animal protein) or 28 to 55 grams (plant protein). The Joint Committee on Defense Production report uses a standard of 30 to 40 grams of protein/person-day. Miller and Scrimshaw set the protein requirement at 35 grams [Ref. 35]. Sobin uses an admittedly high criterion of 60 grams [Ref. 4]. The daily protein requirement range, then, appears to be 20 to 60 grams. Therefore, about 40 grams/person-day would seem a good approximation of the protein requirement for the purposes of post-attack planning.

Again, as in the case of Caloric intake, the U.S. per capita per day consumption of protein is high when compared with postattack standards. In 1976, Americans, on the average, consumed 100 grams of protein daily. For most of the years of this century, protein intake has fluctuated around 95 grams [Ref. 50]. Thus, current protein consumption could be cut 60 percent in the postattack environment, and the basic dietary need for that nutrient would still be met.

c. <u>Other Nutrients</u>

There are, of course, many other relatively less important nutrients. However, inclusion of these other nutrients in a definition of an "adequate" postattack diet would needlessly complicate calculations related to food supply, providing little information of general value to preparedness planners. Reductions in the supply of these other nutrients (thiamine, calcium, phosphorus, iron, riboflavin, iodine, niacin, and vitamins A, D, K, B_6, B_{12}, and C) will not constitute major nutritional problems (by postattack standards) during the first year or so of recovery. This is because these nutrients are distributed among a wide variety of foods and are often stored in, or very efficiently utilized by, the body, or required in small amounts [Ref. 52].

3. Livestock Versus Crops Tradeoff

As previously mentioned, supply of sufficient Calories ($\sim$2,500) would be the preeminent dietary need during the first year. The damage caused by a large-scale nuclear attack would reduce the available food supply through direct destruction or disruption of food distribution networks. Reduction in food supply would concomitantly reduce the total number of available Calories. Several analyses have suggested that the postattack Calorie supply might be stretched through direct human consumption of properly processed plant crops, thus eliminating the comparatively inefficient prior conversion of plant food to meat food by animals [Refs. 43, 55, 56, 57]. Useful descriptions of expedient preparation of wheat, corn, and soybeans can be found in Maintaining Nutritional Adequacy During A Prolonged Food Crisis, a recent report by the Oak Ridge National Laboratory [Ref. 58]. The total supply of Calories available to the population would increase because roughly 7 original plant Calories are required to supply 1 Calorie derived from meat [Ref. 43]. Early studies of postattack agriculture conducted by the Stanford Research Institute concluded that the reallocation of feed grains from livestock to human consumption would be one of the single most effective means of expanding total postattack food production [Refs. 43, 59].

Just as the current U.S. diet could withstand Caloric and protein reductions, so too could it tolerate a shift away from meat and toward more non-meat foods (e.g., grains). Other countries maintain an acceptable standard of nutrition despite a high ratio of vegetable to animal foods. Indeed, in this country, the consumption of grain products has markedly declined during this century as compared with an increase in the consumption of other basic foods. Largely because of a secular rise in the standard of living, Americans as a whole now consume less than half the quantity of grain products they did 60 years ago [Ref. 50]. Based on USDA substitution tables developed for the National Emergency Food Consumption standard diet, per capita nutritional needs could be met through ingestion of 8.5 pounds of cereal or cereal products per week [Ref. 53].

Yet, although some analysts have referred to grain as a "nearly complete food for human consumption" [Ref. 17] and despite the metabolic inefficiency of deriving Calories from meat, there are some significant reasons for not completely liquidating livestock herds in order to increase postattack agricultural efficiency. Three reasons for maintaining some fraction of the surviving livestock herds are provided below.[1]

a. Livestock are not always in competition with man for crop products.

The argument that livestock (cattle, swine, sheep, and poultry) are inefficient food producers due to the loss of Calories in meat production is true only when the foodstuffs consumed by these animals could be directly consumed by man. Livestock are often capable of converting inedible, very coarse, highly fibrous cellulose plant materials (e.g., grass,[2] straw, waste fodder, ground corncobs, and alfalfa) into high-quality food such as meat and milk for man. In addition, in the postattack environment, because the concentration of radioactivity in meat is much less than in an animal's feed, livestock could be used to help screen out radioactive fallout from the food supply [Refs. 2, 43, 60].

The above statements are not true for all livestock, however. Poultry are often, like man, incapable of consuming certain plant materials (ruminants, however, can eat these plants). Poultry, then, will likely compete with man for its feed after a large-scale attack. Thus, as Pogrund argues, "If the postattack environment should limit agriculture crops to a predominance of...fibrous carbohydrates as a source of energy,

---

[1]This discussion is most applicable to those areas of the U.S. where large numbers of livestock might survive an attack. As the results in Section B indicate, few livestock would survive in Ohio.

[2]It might be noted that sufficient pasture grass should be available wherever animal herds survive an attack due to the radioresistance and regeneration capacity of grass [Ref. 57].

then, unless chicken feed will have been stored, the situation would not be optimal for chicken raising." [Ref. 43] This competition between poultry and man for food would be lessened to some extent by feeding unpalatable substances to poultry such as cottonseed, inedible fats, or even soybeans.

Offsetting the disadvantage of consumption by poultry of foodstuffs that could be directly consumed by man is the fact that poultry provides animal protein at a greater level of efficiency than other livestock (with the exception of dairy cattle) [Ref. 43]. This raises the issue of the tradeoffs involved in determining what type of livestock should be supported in the postattack period (assuming a positive decision is made not to slaughter all but a few livestock in order to maximize the Calorie supply). Ruminants can consume roughages and grain by-products not suitable for man (or poultry). Poultry and swine, on the other hand, compete with man for their foodstuffs, but are more efficient in their production of animal protein than the ruminants. It may be that, depending upon local postattack conditions, various "optimal" mixes of cattle, sheep, chickens, and swine might be supported to provide survivors with high-quality protein supplements to a diet based primarily upon grains, which, as discussed below, provide protein less efficiently than does meat.

b. Meat is a better source of protein than plant foods.

An adequate postattack diet has been defined here in terms of both Calories and protein. Animal protein supplies a better balance of essential amino acids than does vegetable protein. Animal products also provide approximately four times the amount of protein per Calorie as do plants [Ref. 43]. Thus, while derivation of Calories directly from plant foods is more efficient than gaining Calories from meats, the protein quality of the diet would suffer (even though protein quantity may be adequate). Protein provided exclusively by plants potentially could supply all the essential amino acids; however, this would require a complex mixture of different plants, a mixture the novitiate vegetarian is unlikely to divine without instruction. Finally, young children would be incapable of eating

enough grain to meet their protein requirements. While adults would not suffer from this problem, their consumption of adequate quantities of grains to satisfy their protein needs might produce flatulence and diarrhea [Ref. 56].

The protein inadequacies of an "expedient" vegetarian diet could be alleviated somewhat by combining soybeans with grains. According to Shinn,

> If an oilseed meal is consumed with grain, the amino acid deficiency of each is compensated for by the other. For example, two parts of ground cereal grain combined with one part of well-processed soybean flour--or cottonseed or peanut flour--provides a mixture with more than 20-percent good-quality, complete protein [Ref. 56].

In addition to soybeans, fish could also be used as a protein supplement to a diet comprised primarily of grains. Following a large-scale attack, extensive damage to ports, loss of ships and manpower, destruction of processing facilities, and disruption of the transportation system would essentially cripple marine fisheries to the extent the they would be unable to augment significantly postattack food supplies. Stocks of inland fish supply could provide 20 days of daily 10-gram protein supplements for the entire U.S. population [Ref. 56].

In sum, some livestock should probably be retained in order to produce meat for protein supplements to the basic postattack diet of grains. While the overriding postattack dietary need is for Calories, the protein requirement is also important. In this regard, animal protein is superior to plant protein.

c. Some livestock will need to be kept alive to allow eventual postattack replenishment of the herds.

Even if the postattack scarcity of food is so great that Caloric requirements cannot be fulfilled, some livestock should be preserved in order to retain the biological basis for the eventual recovery of the herds at a future time when food shortages become less severe. If 90 percent of the female breeding stock died from weapons effects or were

slaughtered to increase the total supply of Calories, it might require 11 years for cattle herds to be completely restored, 7 years for sheep herds, and only a year or less for swine herds and poultry flocks [Ref. 60]. (The rapid repopulation rates of hogs and chickens are additional factors that should be taken into account when determining the "optimal" mix of livestock to be supported in the postattack period.)

4. Food Contamination Danger

One last aspect of the postattack diet requires consideration: the possible health hazard resulting from radiological contamination of food. In general, the deleterious effects of ingestion of contaminated food "are of a protracted nature and their importance is not well understood at present." [Ref. 16] However, to the extent the problem has been studied, there seems to be agreement that the danger of eating contaminated crops is minor relative to the whole body exposure doses accumulated in a fallout contaminated environment [Refs. 16, 5, 61]. Moreover, the fallout particles on the food itself can be readily removed through simple decontamination procedures (e.g., washing, wiping, peeling, and hulling). Based on work done at the UT-AEC Agricultural Research Laboratory, it appears that the majority of surviving, but irradiated, sheep and cattle eventually could be used for food in the postattack period [Ref. 62].

B. STORED FOOD

1. Introduction

The stocks of food on hand in Ohio as part of the normal economic operation of the state represent the major potential source of food for the postattack environment. Since it is likely that the production of food would be temporarily interrupted following an attack, only food actually present at the time of the attack was considered in this study. (Postattack production of food will be addressed later in this chapter.) Furthermore, since it is also likely that transportation would be disrupted,

Ohio was taken to be isolated; i.e., it was assumed that no food would enter or leave the state.

Three potential sources of food were considered. These three were crops, farm animals, and processed food within the food distribution system. Of the three, the most significant in terms of quantity and reliability were crops; specifically, grains and soybeans.

Once the normal stocks of food were known, the next step was to estimate what portion of this "inventory" would be destroyed by the attack. This section first discusses the data on peacetime supplies of food and distribution and then the attack and its effect on the food stocks.

In the following calculations, it was estimated that the average person would consume 2,500 Calories per day, in accordance with the discussion in Section A of this chapter. However, no attempt was made to consider a nutritionally balanced diet. For the short-term question of survival, the most important aspect of diet is simply the number of available Calories. Most of the crop production figures are averages of the productions for the three years 1975-1977.

2. Crops

Stores of grains and soybeans represent the least vulnerable and largest supply of food in the event of attack. Large quantities of wheat, corn, and soybeans are kept in storage as part of the normal economic system of farm operation. Much of these stores are kept on farms and thus are well dispersed and relatively safe from attack. These crops also have long storage lifetimes.

Yearly production of all crops in Ohio is detailed in Table 9. The number of harvested acres of each crop is shown. The next column lists the number of Calories that can be derived from an acre of each crop for feeding people. Total Calories produced in 1 year is shown in the next column. Also shown are the amounts of several crops reamining in storage for various months of the year.

TABLE 9. OHIO CROP PRODUCTION AND ASSOCIATED AVAILABLE CALORIES IN ONE YEAR

Crop	Harvested Acres (10^3)	Food Value (10^6 Cal/Acre)	Available Calories (10^9)	Percentage of Production in Storage by Month											
				1	2	3	4	5	6	7	8	9	10	11	12
Corn, Grain	3,600	4.30	15,500[a]	72			50		33				9		
Corn, Silage	240	4.30	1,032[a]												
Corn, Sweet	14	4.30	60												
Popcorn	10	4.30	43												
Soybeans, Beans	3,100	2.20	6,820[a]	66			50		29			8			
Oats	470	.89	418[a]	57			36		22				88		
Barley	11	1.21	13												
Rye	7	1.21	8												
Alfalfa	560			62			18								
Other Hay	970			62			18								
Wheat	1,600	1.39	2,224	64			44		28				84		
Potatoes	13	5.23	68	27	17	9	6						38		
Sugar Beets	35	15.05	525												

Total available Calories from production of one year: Case I = $2,940 \times 10^9$; Case II = $26,700 \times 10^9$

Case I $\dfrac{2.9 \times 10^{12}\ \text{Cal}}{2,500\ \text{Cal/person-day} \times 10.7 \times 10^6\ \text{people}} = 109$ days

Case II $\dfrac{26.7 \times 10^{12}\ \text{Cal}}{2,500\ \text{Cal/person-day} \times 10.7 \times 10^6\ \text{people}} = 998$ days

[a]Normally used for animal feed.

Source: References 63 and 64.

Corn, wheat, and soybeans account for 80 percent of the total harvested acreage in Ohio, and more than 90 percent of the available Calories. However, whereas wheat is used for human consumption, corn and soybeans are used primarily as animal feed. Therefore, the total number of Calories that would be available for human consumption after an attack would be heavily dependent on how much of the crops normally used to feed animals was diverted to feeding humans. For this reason, two numbers are shown at the bottom of the table for the total available Calories for feeding humans from 1 year's crop production, corresponding to two different cases.

In Case I, only the crops normally consumed by humans are counted. Of the total 2.9×10^{12} Calories produced in one year, 76 percent are supplied by wheat. Thus, the amount of food available in this case will be strongly dependent on the time of the attack in terms of the wheat harvest and storage cycle. Figure 28 shows the amount of wheat in storage versus the time of year. An attack on October 1 would occur when the largest amount of wheat, 84 percent of the total production for the year, is in storage. Using the present population of Ohio, 10.7 million, and the expected consumption rate of 2,500 Calories per person per day, this corresponds to a 70-day supply of food. An attack on June 1, however, would occur when wheat stocks were at their lowest, leaving only a 25-day supply of food.

In Case II, crops that are normally used to feed animals are counted in the total for feeding humans. This corresponds to total diversion of crops for animal feed to human consumption. Because feeding crops to animals and then feeding the animals to people is less efficient in terms of Caloric intake than feeding the crops directly to people, Case II might be closer to the best use of crops under postattack conditions. Of course, preservation of relatively small numbers of animals for future rebuilding of the animal population would be necessary. However, since Case II is the limiting case, it was considered worth examining. As will be discussed in the postattack portion of this chapter, it was also found that extremely few farm animals survived the attack, and so Case II corresponds closely to the actual postattack situation.

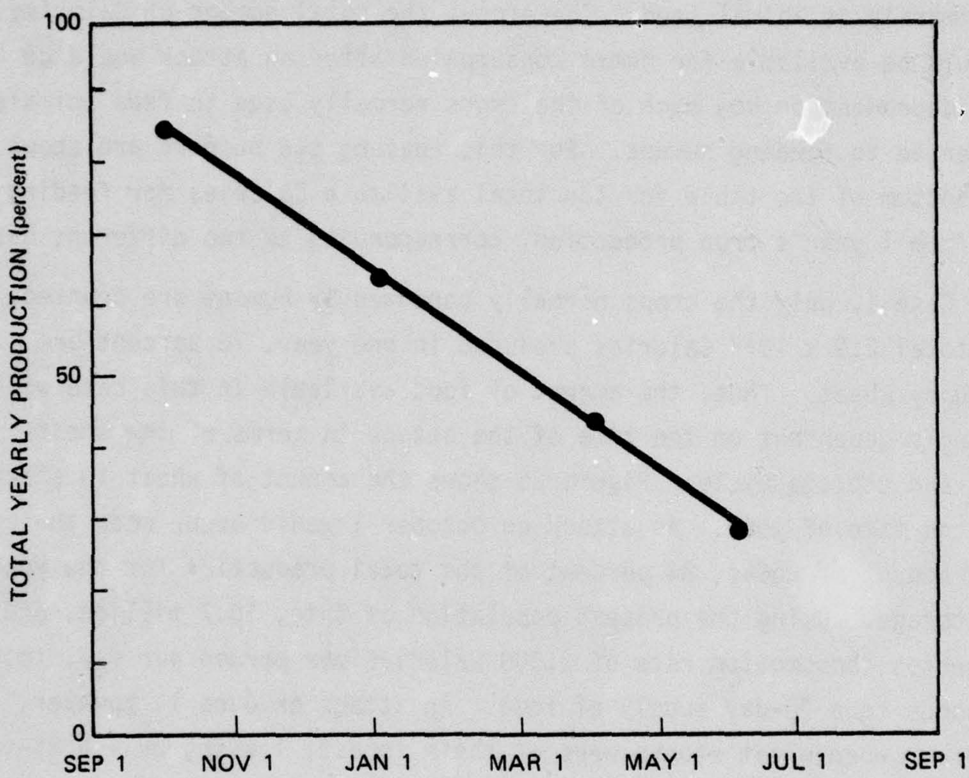


FIGURE 28. WHEAT IN STORAGE VS TIME OF YEAR

As can be seen in Table 9, Case II shows a large increase in the number of Calories available for human consumption. Now the major source of Calories becomes corn and soybeans. The Calories resulting from these two crops, which are harvested and stored on about the same schedule, amount to 84 percent of the total Calories from all crops. The amount of available food is again dependent on the time of year, but now the corn schedule is dominant. Figure 29 shows the amount of corn in storage versus the time of year. On January 1, 74 percent of the total corn production and 67 percent of the total soybean production is in storage. This represents a 620-day supply of food. On October 1, however, corn stocks have dropped to 9 percent and soybeans to 8 percent, which amounts to a 130-day supply. Table 10 summarizes the supply of food from crops for the two cases.

TABLE 10. SUMMARY OF SUPPLIES OF CROPS IN OHIO

Case I:

No Diversion of Animal Feed Crops

Date of Attack	Food Supply in Days (Wheat)
October 1	70 (maximum)
June 1	25 (minimum)

Case II:

Total Diversion of Animal Feed Crops

Date of Attack	Food Supply in Days (Wheat, Corn, and Soybeans)
January 1	620 (maximum)
October 1	130 (minimum)

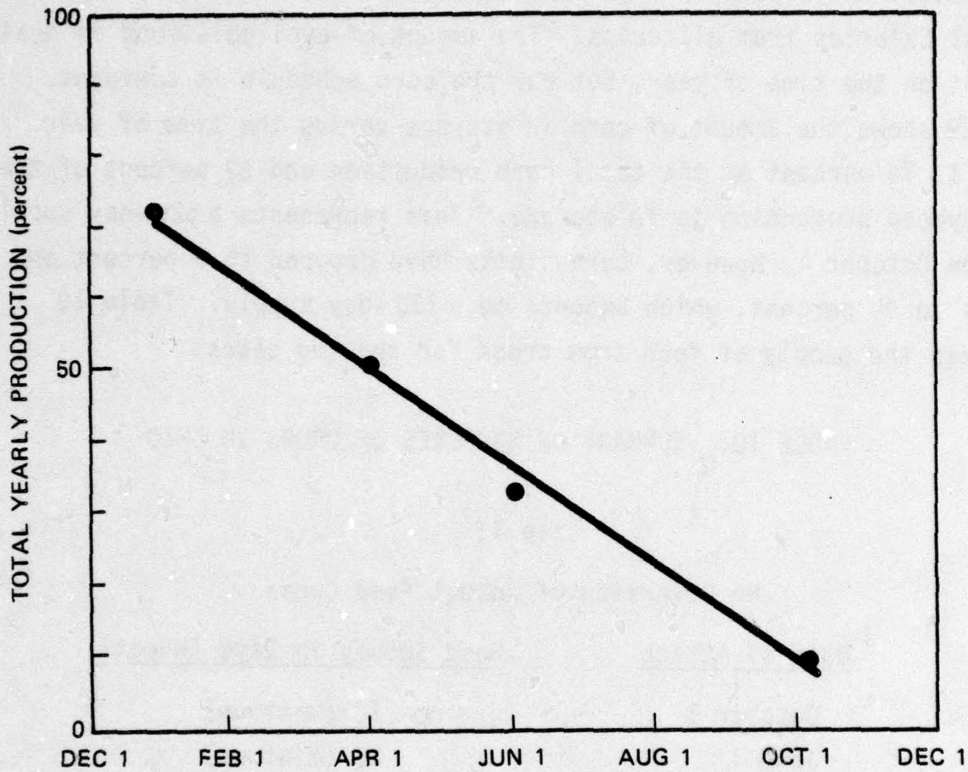


FIGURE 29. CORN IN STORAGE VS TIME OF YEAR

3. Farm Animals

The availability of food from farm animals is not as clear an issue as from crops. First, the animals are far more vulnerable to the attack than crops. Second, as was previously discussed, it may be advisable to divert most animal-feed crops to human consumption, and slaughter most of the animal population. In either situation, it might be possible to salvage the animals for meat if some basic method for preserving the meat were available. However, present meat processing facilities tend to be concentrated in urban areas and are likely to be destroyed. It is unlikely that the remaining facilities could process the sudden flow of animals resulting from either of the two situations. Because of these considerations, it may be better to consider farm animals as a potential, but not necessarily reliable, source of food, or as a protein supplement to a primarily grain-based postattack diet. However, in order to complete the inventory of food on hand in Ohio, an assessment was made of the supply of meat available from farm animals. Table 11 details this supply. The total number of animals on hand was multiplied by a factor that predicts the number of days the food from one animal can support one person. These factors were adopted from a paper by Garland [Ref. 65]. The total for this method, which includes sheep, chickens, and turkeys, was 60 days.

4. Stocks of Food Within the Food Distribution System

There are several points within the food distribution system where potential supplies of food are located. The four major points are households, retail stores, wholesale suppliers, and food processors. A fifth possible source of food is eating establishments, either public or those associated with schools, hospitals, etc. However, these are believed to have only about a 2-day supply [Ref. 66]. Also there may be about a half-day supply of food actually in transportation at any moment [Ref. 67]. These last two sources were neglected.

TABLE 11. SUPPLY OF MEAT FROM ANIMALS ON HAND IN OHIO

	Number of Animals on Hand (10^3)	Conversion Factor (Person-Days/Animal)	Person-Days (10^6)
Cattle	2,250	161	362
Swine	1,825	133	243
Sheep	423	20.8	8.8
Chickens	11,500	0.56	6.4
Turkeys	3,098	4.2	13.0
Total			633.2

$$\frac{633.2 \times 10^6 \text{ person-days}}{10.7 \times 10^6 \text{ people}} = 60 \text{ days}$$

The last detailed studies of stocks of food in the distribution system were performed by the Economic Research Service of the USDA from 1957 to 1964 [Ref. 68]. These studies provided estimates for stocks of food on the county level across the United States. Although they are several years old, they were cited in a 1977 report by the USDA [Ref. 66] as still being generally accurate [Ref. 67].

In the USDA studies, the consumption rate was estimated to be 2,000 Calories/person-day. The figures shown here were adjusted to reflect a rate of 2,500 Calories/person-day. Seasonal variations in food supplies in the distribution system in Ohio were found to be small, amounting to only about 3-day difference between the high point in January and the low point in July. Table 12 lists the number of days available from each of the four major distribution sources and the total.

TABLE 12. STOCKS OF FOOD WITHIN THE FOOD DISTRIBUTION SYSTEM IN OHIO

Source	Supply of Food (days)
Households	10
Retail Stores	12
Wholesale Warehouses	11
Food Processors	20
Total	~50

5. Preattack Supplies--Statewide

The total supply of food available from crops, farm animals, and the food distribution system is shown in Table 13. It is clear that even with the addition of food from farm animals and the distribution system, the total supply is still strongly influenced by the crops and the date of

TABLE 13. PREATTACK TOTAL SUPPLIES OF FOOD IN OHIO

	Case I (Animals preserved, feed crops not diverted to human consumption)		Case II (Animals eaten, feed crops diverted to human consumption)	
	October 1	June 1	January 1	October 1
Crops (days)	70	25	620	130
Farm Animals (days)	-	-	60	60
Food in Distribution System (days)	50	50	50	50
Total (days)	120 (maximum)	75 (minimum)	730 (maximum)	240 (minimum)

attack. For this reason, totals are shown for the dates corresponding to the maximum and minimum supplies for each of the two cases of crop use discussed earlier. The total supply of food on hand in Ohio ranges from a minimum of 75 days on June 1 under Case I to a maximum of 730 days on January 1 under Case II.

6. Preattack Supplies--County-Level Data

The next step in the process of assessing food supplies in Ohio was to estimate the food reserves for each of Ohio's 88 counties. First, this is an important piece of information in itself, since rural areas that produce food but have small populations will obviously have an excess of food compared with urban areas that have larger populations. Second, in order to estimate the damage done by the attack to the food supplies, it is first necessary to know the location of the food within the state.

County-level data on crop production, farm animal populations, and processed food are available from USDA [Ref. 63]. For animals and processed food, estimating the amount of food available in each county is straightforward. The situation for crops, however, is more complicated.

As has already been shown, corn, wheat, and soybeans are all harvested and stored on a different yearly schedule. Corn and soybeans tend to parallel each other, whereas the wheat schedule is skewed from the others by several months. Moreover, the location of storage, either on or off farms, which is known as the grain "position," is also different for each crop. Table 14 shows the fraction of the year's production of each crop that is in storage on January 1 and October 1 and the fractions of this that are on farms and off farms.

Corn, which is used primarily as animal feed, is stored for the most part on the farms. Wheat, on the other hand, which is used for human consumption, is transported off the farms for processing and shipping and so tends to accumulate in storage facilities in large industrial centers. Soybeans, which are used mostly for animal feed but which are processed first, fall between corn and wheat in terms of the fraction stored on farms.

TABLE 14. CROPS IN STORAGE POSITIONS IN OHIO FOR JANUARY 1 AND OCTOBER 1

	Percent of Harvest in Storage		Percent of Storage on Farms		Percent of Storage off Farms	
	Jan 1	Oct 1	Jan 1	Oct 1	Jan 1	Oct 1
Corn	74	10	67	51	33	49
Soybeans	67	8	50	40	50	50
Wheat	64	84	17	20	83	80

Unfortunately, Ohio keeps no records of the actual amounts of grain in storage at individual commercial facilities. However, storage facility capacities are tabulated by county [Ref. 69]. These capacities are shown in Figure 30. This data allowed estimates to be made of the amount of grain in storage in a county by apportioning the amount of the crop in off-farm storage to each county on the basis of storage site capacity.

The totals for the amount of food (crops, farm animals, and processed food) on hand in each county were prepared. Figures 31 and 32 show the results for the two times already discussed, January 1 and October 1. The amount of food in each county is measured in man-days; i.e., units of 2,500 Calories. The darker a county is shown, the more food it has. In order to put the data in more intuitive form, a second scale is shown. This scale indicates how long the food supply in each county would last if the present population of Ohio was divided evenly among the 88 counties. The maps clearly show that the western region is the food-producing portion of the state. The light band running along the southeast side of the state corresponds to the coal mining areas, which produce relatively little food.

The population, of course, is not spread uniformly across the state. Because of this, the duration of the food supplies in a county will be dependent on the population. Figures 33 and 34 show the actual expected duration of the food supplies in each county based on the present peacetime distribution of the population for the two dates of attack. Since

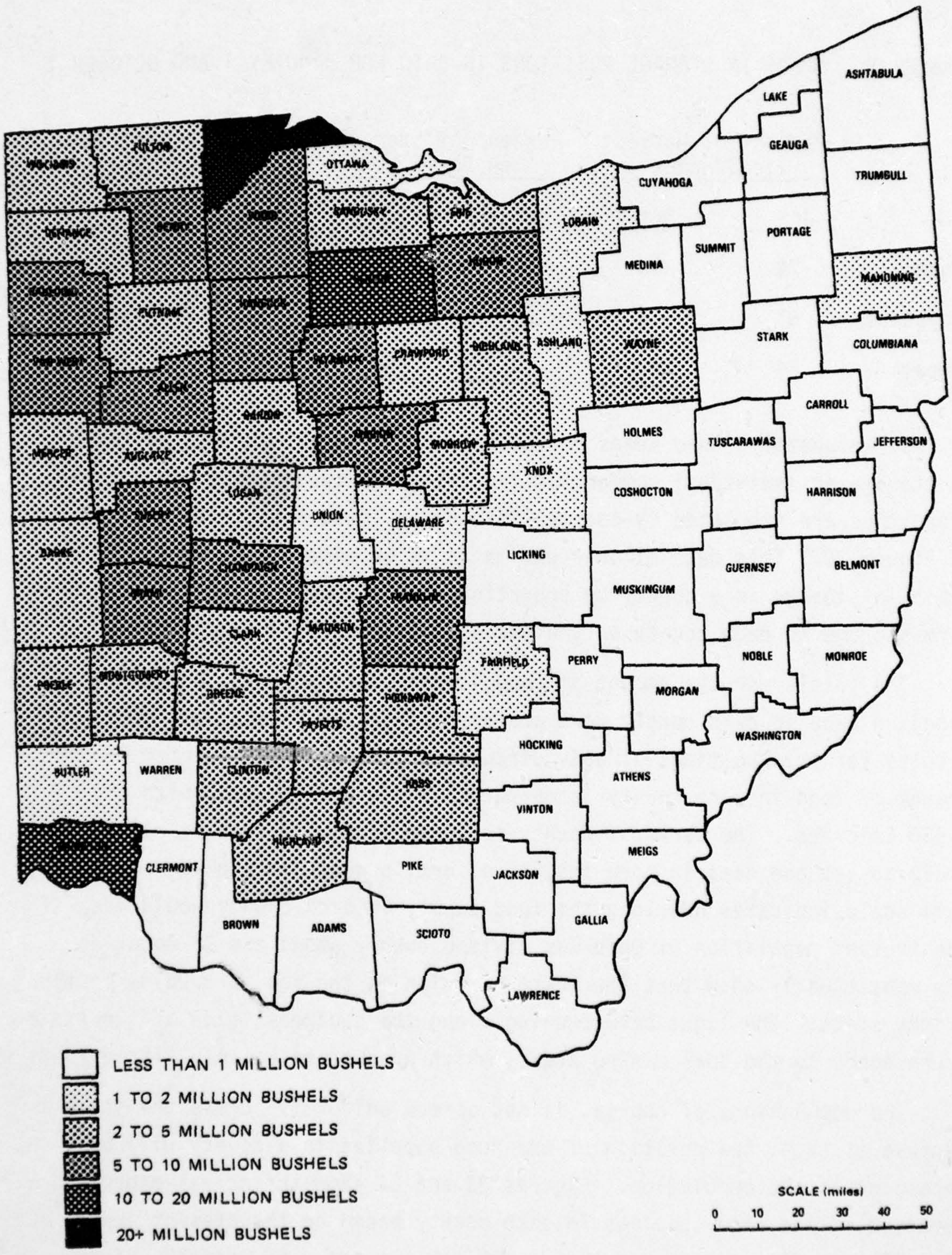
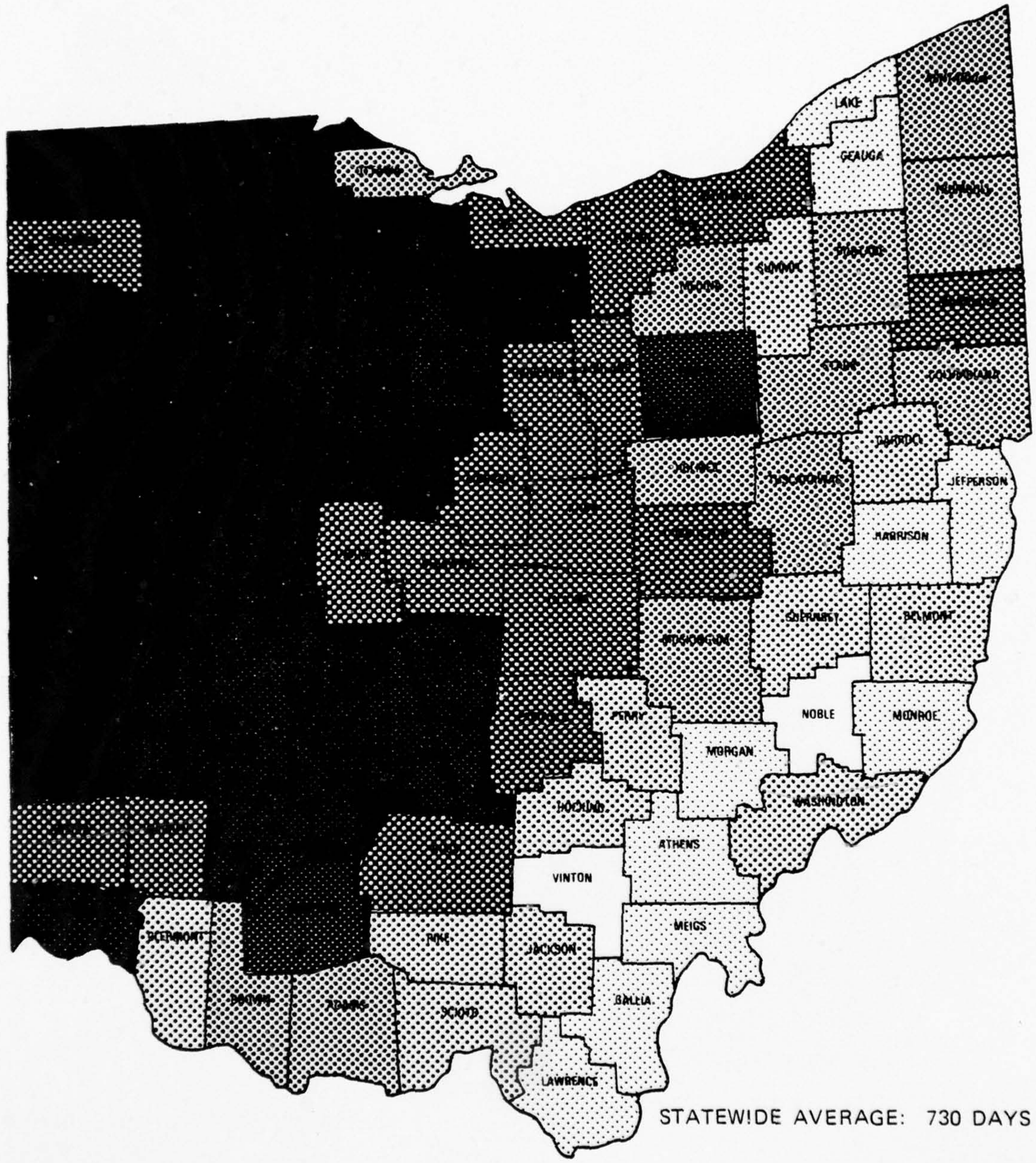
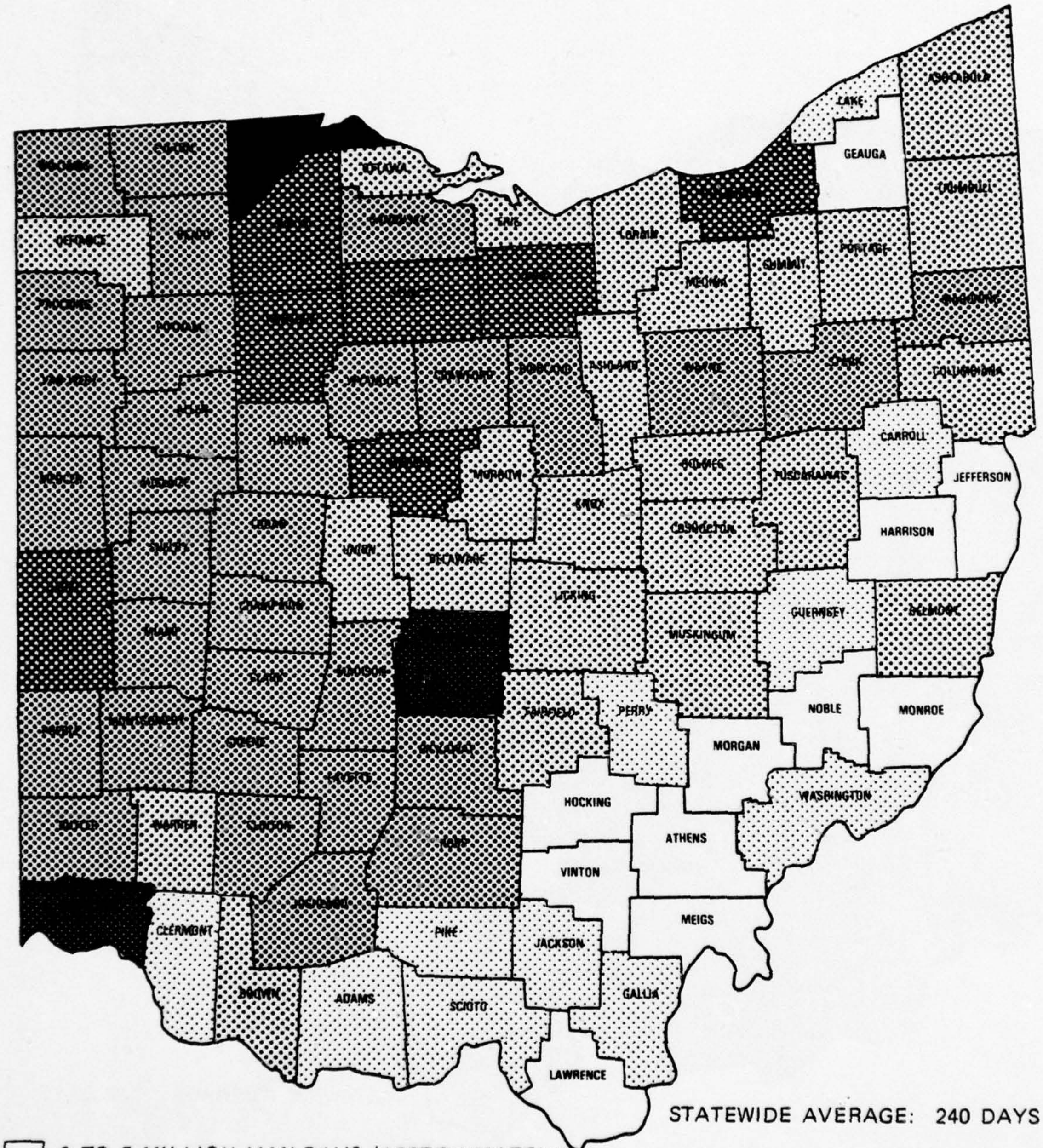


FIGURE 30. GRAIN STORAGE CAPACITIES IN OHIO



- 0 TO 5 MILLION MAN-DAYS (APPROXIMATELY 0 TO 40 DAYS SUPPLY FOR AVERAGE COUNTY POPULATION)
- 5 TO 10 MILLION MAN-DAYS (40 TO 80 DAYS)
- 10 TO 25 MILLION MAN-DAYS (80 TO 205 DAYS)
- 25 TO 50 MILLION MAN-DAYS (205 TO 410 DAYS)
- 50 TO 100 MILLION MAN-DAYS (410 TO 820 DAYS)
- 100 MILLION MAN-DAYS OR MORE (820 DAYS OR MORE)

FIGURE 31. PREATTACK FOOD SUPPLIES ON HAND IN OHIO ON JANUARY 1



0 TO 5 MILLION MAN-DAYS (APPROXIMATELY 0 TO 40 DAYS SUPPLY FOR AVERAGE COUNTY POPULATION)
5 TO 10 MILLION MAN-DAYS (40 TO 80 DAYS)
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25 TO 50 MILLION MAN-DAYS (205 TO 410 DAYS)
50 TO 100 MILLION MAN-DAYS (410 TO 820 DAYS)
100 MILLION MAN-DAYS OR MORE (820 DAYS OR MORE)

SCALE (miles)
0 10 20 30 40 50

FIGURE 32. PREATTACK FOOD SUPPLIES ON HAND IN OHIO ON OCTOBER 1

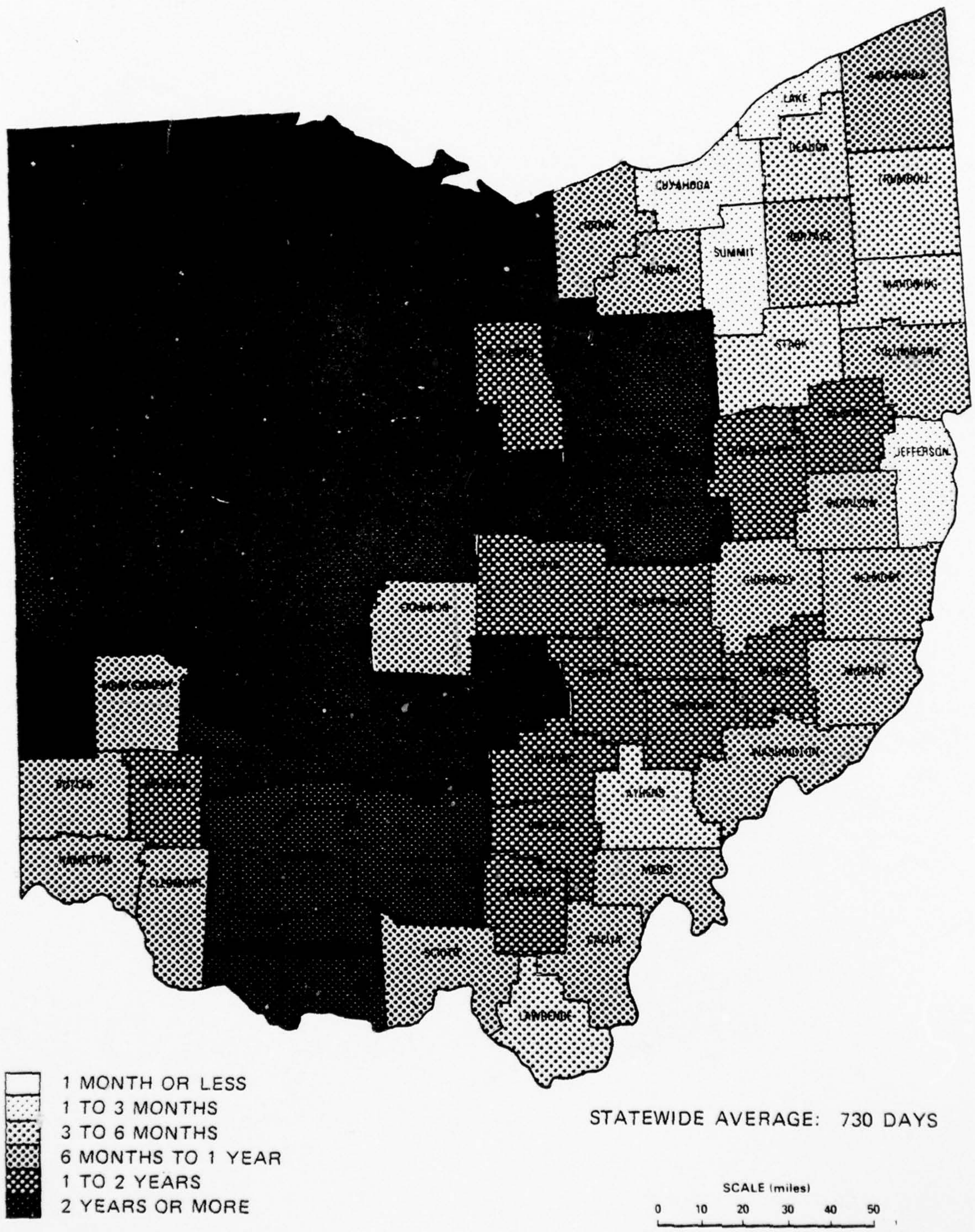

FIGURE 33. DURATION OF PREATTACK FOOD SUPPLIES ON HAND IN OHIO ON JANUARY 1 FOR NONRELOCATED POPULATION

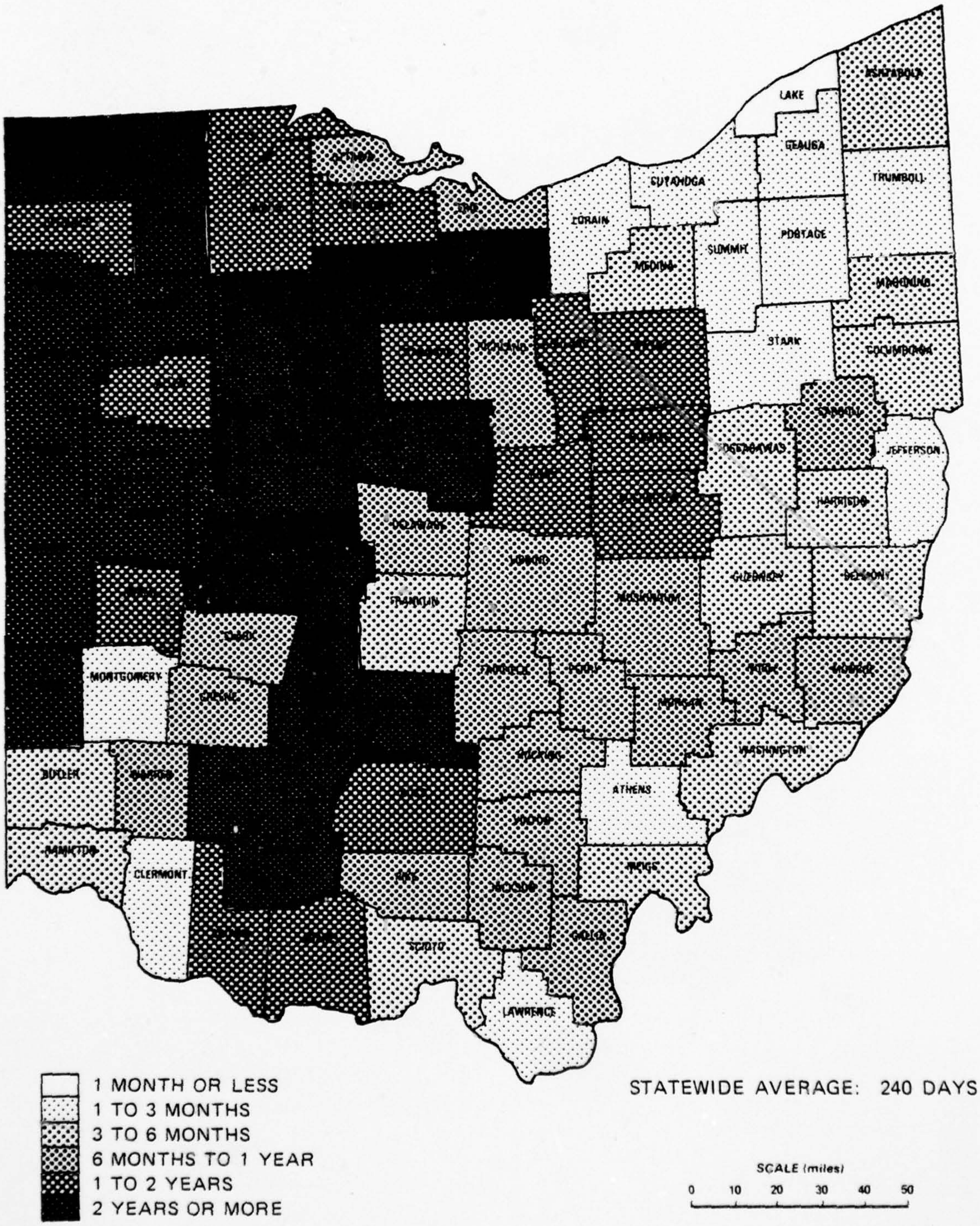

FIGURE 34. DURATION OF PREATTACK FOOD SUPPLIES ON HAND IN OHIO ON OCTOBER 1 FOR NONRELOCATED POPULATION

population tends to be least dense in exactly those counties where the most food is, the western counties have very long duration times and appear the darkest.

Finally, Figures 35 and 36 show the expected duration of food supplies for relocated population. Since the population is distributed more evenly in this situation, the supply of food is spread somewhat more evenly among the population, although the western counties still have longer duration times.

7. Damage Assessment

a. Grains

Each of the three sources of food has a different vulnerability to the attack. Grains, once in storage, are safe from fallout and radiation. Furthermore, the grain stored on farms is safe from blast, since the rural areas are, for the most part, unaffected by blast under this attack. This means that most of the corn and soybeans would survive the attack. Much of the wheat, however, since its storage is centralized in urban areas, is lost. In estimating the losses due to the attack, any grain in storage in areas receiving 5 psi or more overpressure was considered destroyed. This was considered to be a conservative assumption since it might be possible to salvage some of the stored grain in destroyed facilities.

b. Farm Animals

Farm animals are also unaffected by blast since they too are located principally in rural areas. However, they are very susceptible to radiation. In fact, the study showed that extremely few swine and cattle, which make up the vast majority of the meat supply, would survive the attack.

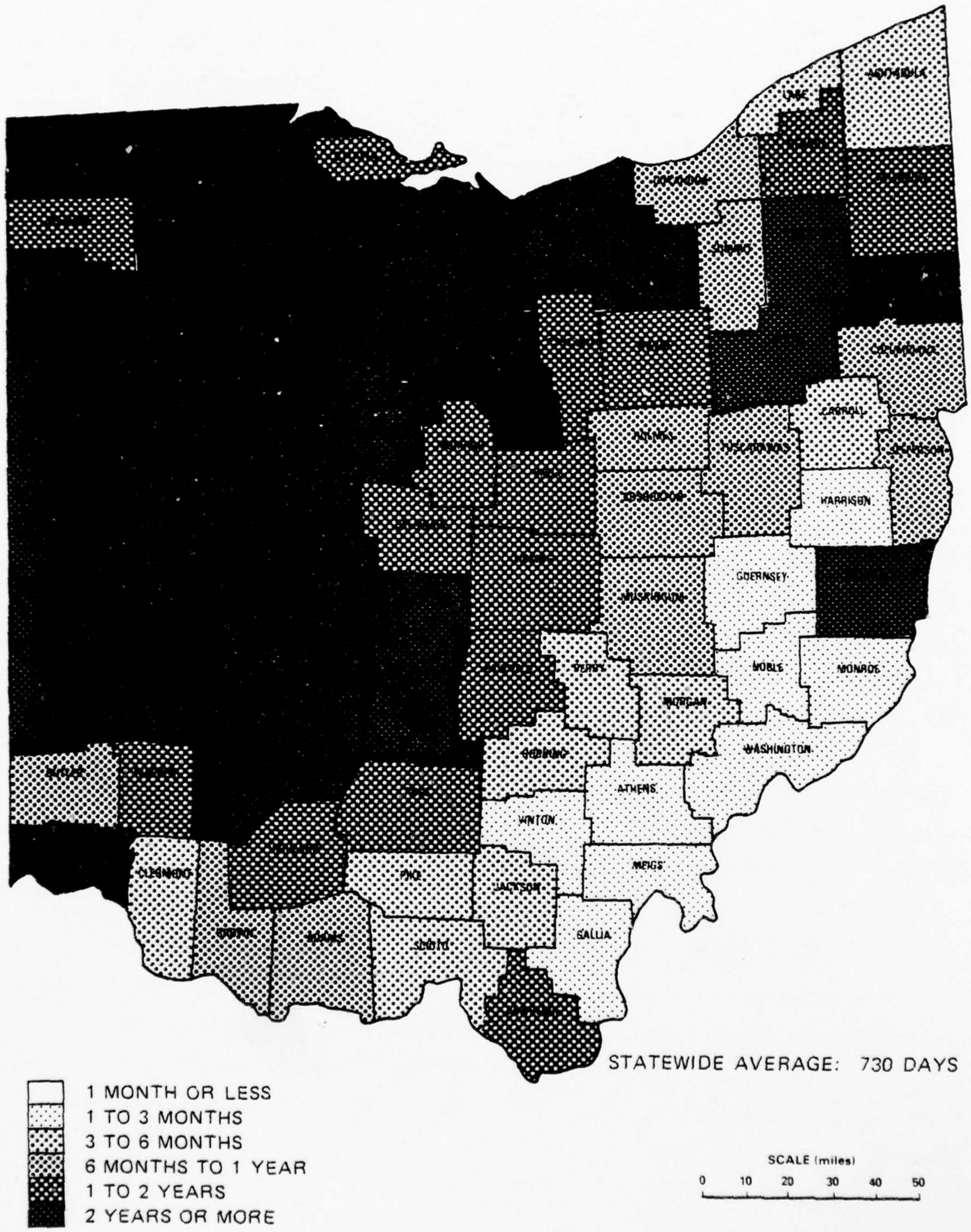

FIGURE 35. DURATION OF PREATTACK FOOD SUPPLIES ON HAND IN OHIO ON JANUARY 1 FOR POPULATION RELOCATED BY SPC METHOD

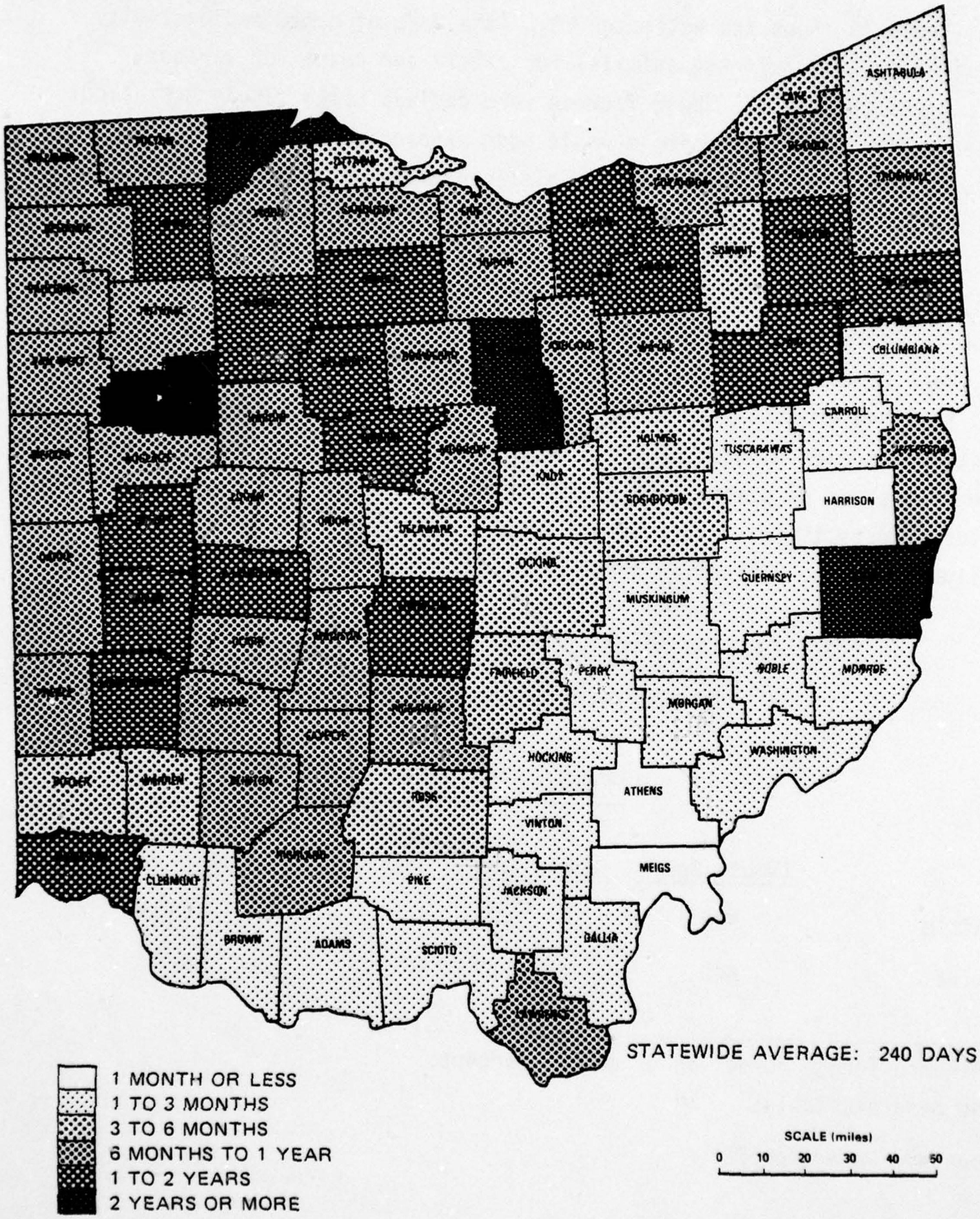

FIGURE 36. DURATION OF PREATTACK FOOD SUPPLIES ON HAND IN OHIO ON OCTOBER 1 FOR POPULATION RELOCATED BY SPC METHOD

Table 15 shows the estimated LD_{50} (the dose of gamma radioactivity required to kill half the animals) for cattle and swine for various situations [Ref. 70]. These figures were derived using simulated fallout experiments rather than simple whole body exposures. Hence, lethality figures are markedly different for different types of circumstances. Animals confined in buildings such as barns or hog houses receive only whole body gamma radiation from the fallout deposited on or around the buildings. In pens or corrals, however, the animals receive both the whole body radiation and a further dose of beta radiation from fallout deposited on their backs. This has an additional weakening effect on the animals, and thus the effective gamma LD_{50} is lower. Finally, animals that are in pasture are even more susceptible because they ingest fallout that has been deposited on plants. As can be seen in this table, cattle are particularly susceptible to this effect because they are ruminants, and the fallout tends to collect in their gastrointestinal tract.

TABLE 15. ESTIMATED LIVESTOCK LETHALITY ($LD_{50/60}$) FROM FALLOUT-GAMMA-RADIATION EXPOSURE ALONE AND IN COMBINATION WITH BETA RADIATION

	$LD_{50/60}$ Total Gamma Exposure, R		
	Barn (Whole Body)	Pen or Corral (Whole Body + Skin)	Pasture[a] (Whole Body + Skin + GI)
Cattle	500	450	180[a]
Swine	640	600[b]	550[b]

[a]Assumed forage retention of 7 to 9 percent.

[b]No data available.

Source: Reference 70.

Clearly, the animals that are the safest are those that could be confined to barns. However, farms in Ohio generally tend not to have enough buildings to house all the cattle and swine on hand. Moreover, even inside the barns the animals would not be safe. Table 16 shows lethality doses for cattle and swine versus doses for simple whole body radiation, which would be the case for animals confined in barns [Ref. 71]. Table 17 shows the PF factors associated with common farm buildings. The data from the three tables were extrapolated and combined with the fallout patterns discussed in the section on the attack to produce Figures 37 and 38. These show the areas in Ohio that receive radiation doses high enough to kill at least 90 percent of all cattle or swine for various shelter circumstances; i.e., whether the animals are in buildings, pens, or fields. Only in a narrow band across the center of the state was the fallout low enough for any significant number of cattle and swine to survive. Since the few animals that did survive would have to be saved for breeding, the attack would effectively destroy the entire supply of meat in Ohio, except, of course, for that which was already processed.

TABLE 16. ESTIMATED SURVIVAL OF LIVESTOCK CONFINED IN BARNS OR OTHER STRUCTURES FROM GAMMA EXPOSURE[a]

Cattle		Swine	
Exposure (R)	Survival (%)	Exposure (R)	Survival (%)
0 - 250	100	0 - 350	100
300	95	400	90
400	90	500	70
500	50	660	50
600	10	800	10

[a]Exposure given is that actually received over the period 96 to 120 hours after fallout deposition.

Source: Reference 71

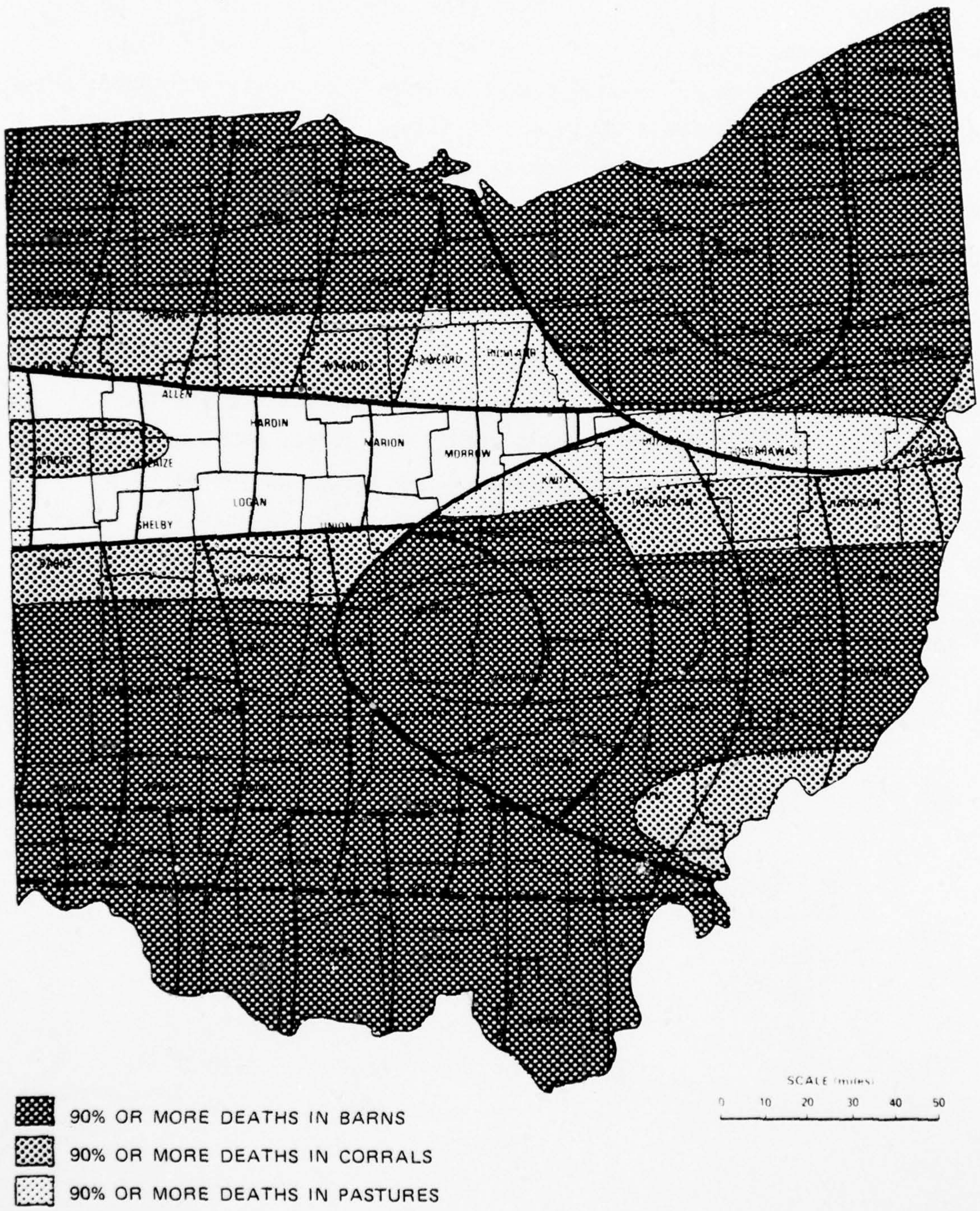

FIGURE 37. AREAS OF LD_{90} FOR CATTLE FOR VARIOUS SHELTER CONDITIONS

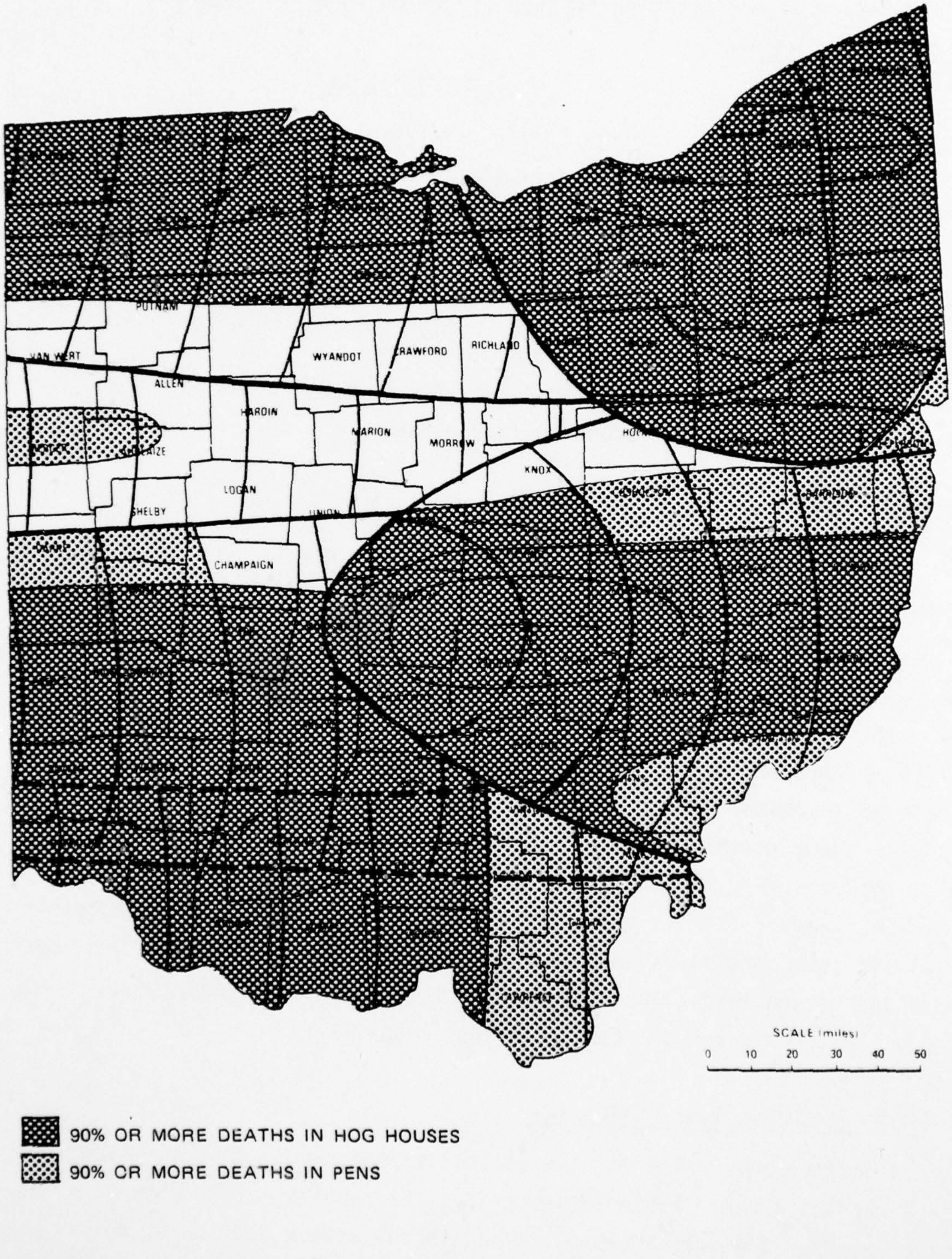

FIGURE 38. AREAS OF LD_{90} FOR SWINE FOR VARIOUS SHELTER CONDITIONS

TABLE 17. PROTECTION OFFERED BY COMMON FARM STRUCTURES

PF	Type of Shelter
10-20	Large barns, concrete or masonry
2.5-5	Large frame barns
2-3	Conventional frame barns
2	Conventional hoghouse (part concrete block)
2.5-5	Full masonry or concrete block hoghouse
1.25-1.7	Pole barns, loafing sheds, stock confined under roof
5	Multistory poultry houses, masonry
1.1-3.3	Other poultry houses

Source: Reference 71

c. Processed Food

Processed food is vulnerable only to the blast effects of the attack. Once food is packaged, it is safe from fallout contamination. Much of this food, unfortunately, is in warehouses, packing plants, and processing facilities that tend to be concentrated in urban areas. (Only about 20 percent of processed food is in households.) Because of this, it was estimated that, in counties that had urban areas that were destroyed by blast, approximately 80 percent of the processed food stocks would be destroyed. Again, this is a conservative assumption. It might be possible to salvage some portion of the processed and packaged food even in destroyed plants and warehouses. Those counties that suffered no direct blast effects were considered to retain all such supplies.

8. Postattack Supplies--Statewide

Using the above criteria, the statewide food supply that survived the attack was estimated. Table 18 summarizes the results, along with data for fatalities from the attack (as described in the attack section of this report).

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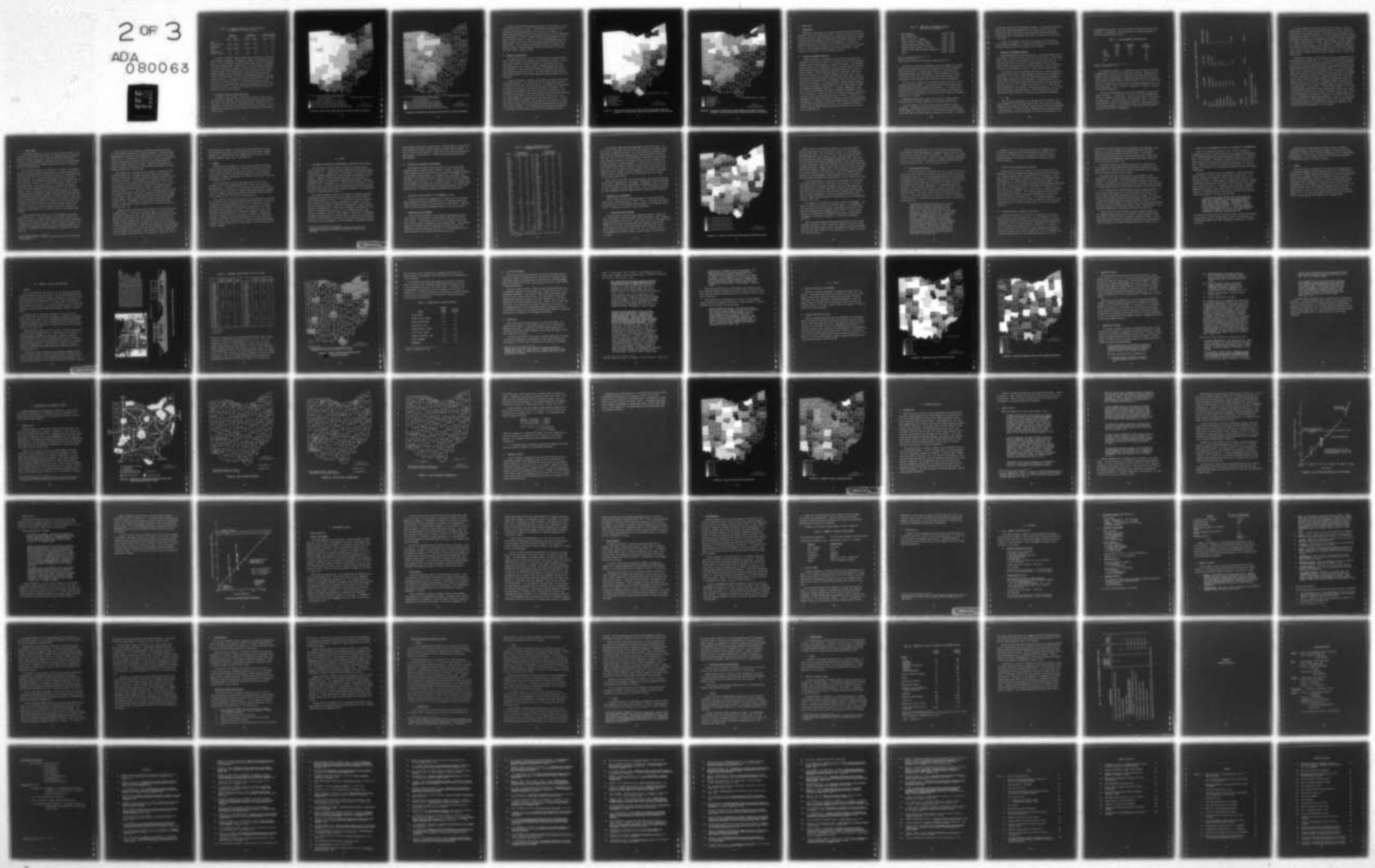

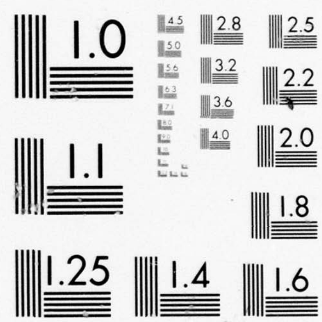
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1.1
1.8
1.25
1.4
1.6

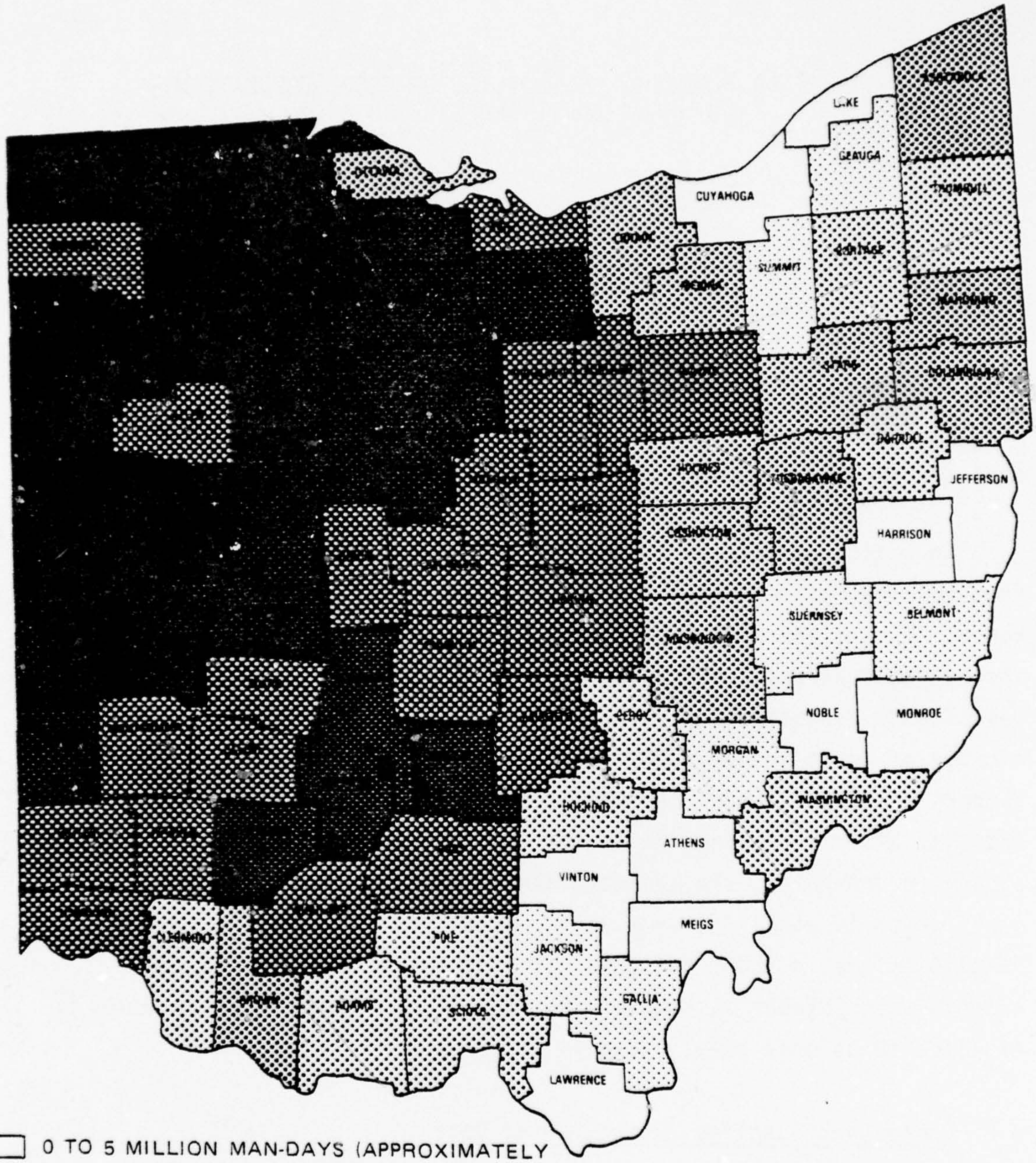
TABLE 18. SUMMARY OF SUPPLIES OF FOOD, POPULATION, AND DURATION OF SUPPLIES IN OHIO

	Preattack		Postattack		Percent Change	
	Jan 1	Oct 1	Jan 1	Oct 1	Jan 1	Oct 1
Food (10^6 man-days)	7,800	2,600	6,400	1,500	-18	-41
Population (10^3)	10,700	10,700	8,700	8,700	-18	-18
Duration of Supplies (days)	730	240	740	180	+1	-28

An attack on January 1 destroys approximately 18 percent of the total food reserves of the state. On October 1, however, the situation is much worse. First, the amount of food in storage is much smaller, and second, the attack destroys about 41 percent of it. This is primarily because, as was already discussed, on October 1, most of the food is wheat, and the storage of wheat is very centralized. Since the attack kills the same numbers of people, about 18 percent, on either date, the duration of supplies after the attack in October is considerably shortened. For the attack on January 1, the expected duration of food supplies is about 740 days, which is about the same as it was before the attack since the fatalities are in about the same ratio as the destruction of food. Given an attack on October 1, however, the duration of food supplies would be expected to be only about 180 days.

9. Postattack Supplies--County-Level Data

Estimates of the supplies of food that survived the attack in each county were also prepared. Figures 39 and 40 show these supplies for the two dates. These maps parallel the preattack maps, Figures 31 and 32 shown earlier. Note that the alternative scale has now changed. This is because the average population per county is now based on the 82 percent survival rate.

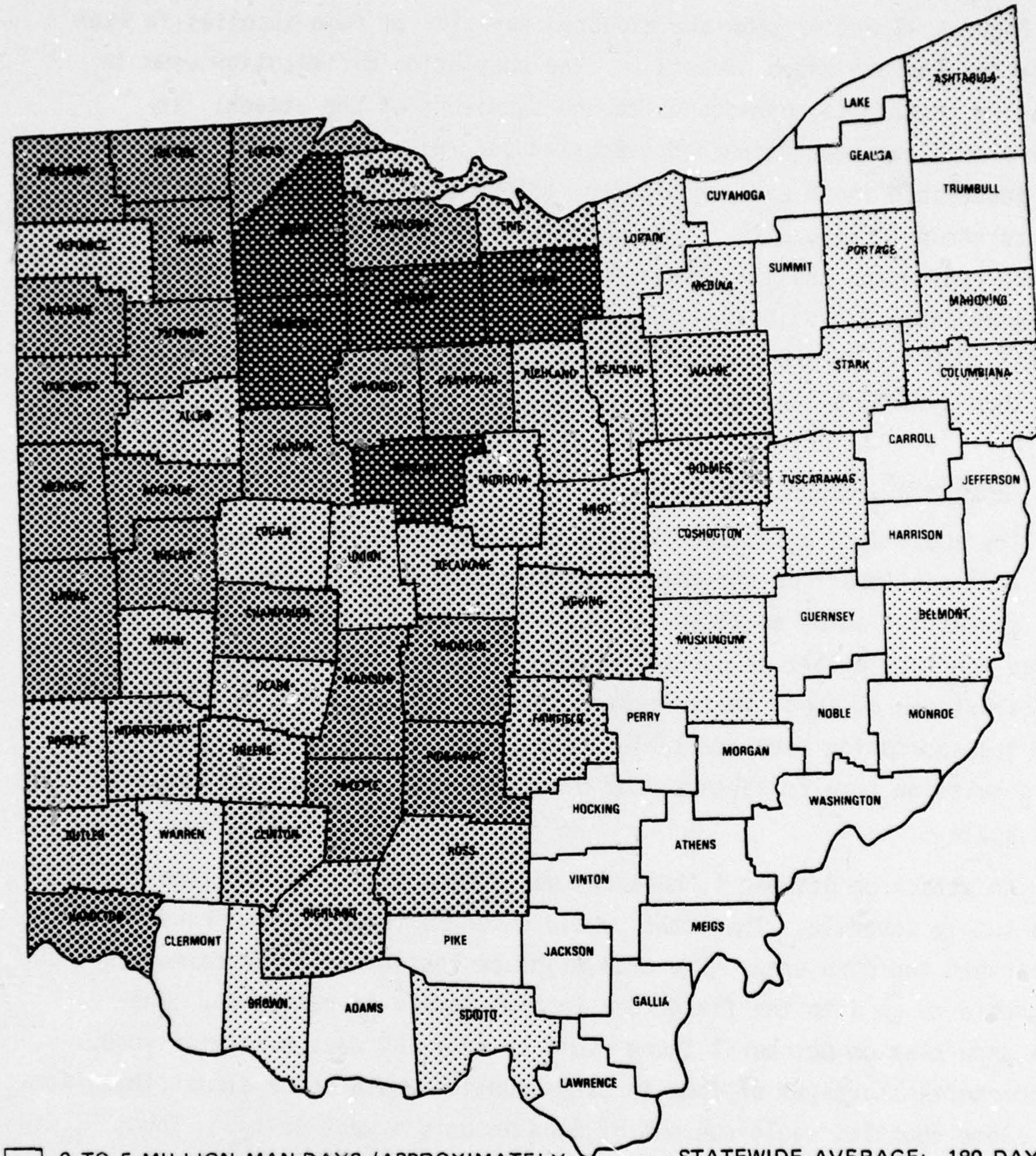


0 TO 5 MILLION MAN-DAYS (APPROXIMATELY 0 TO 50 DAYS SUPPLY FOR AVERAGE COUNTY POPULATION)
5 TO 10 MILLION MAN-DAYS (50 TO 100 DAYS)
10 TO 25 MILLION MAN-DAYS (100 TO 250 DAYS)
25 TO 50 MILLION MAN DAYS (250 TO 500 DAYS)
50 TO 100 MILLION MAN-DAYS (500 TO 1000 DAYS)
100 MILLION MAN-DAYS OR MORE (1000 DAYS OR MORE)

STATEWIDE AVERAGE: 740 DAYS

SCALE (miles)
0 10 20 30 40 50

FIGURE 39. POSTATTACK FOOD SUPPLIES ON HAND IN OHIO ON JANUARY 1



0 TO 5 MILLION MAN-DAYS (APPROXIMATELY 0 TO 50 DAYS SUPPLY FOR AVERAGE COUNTY POPULATION)

5 TO 10 MILLION MAN-DAYS (50 TO 100 DAYS)

10 TO 25 MILLION MAN-DAYS (100 TO 250 DAYS)

25 TO 50 MILLION MAN-DAYS (250 TO 500 DAYS)

50 TO 100 MILLION MAN-DAYS (500 TO 1000 DAYS)

100 MILLION MAN-DAYS OR MORE (1000 DAYS OR MORE)

STATEWIDE AVERAGE: 180 DAYS

FIGURE 40. POSTATTACK FOOD SUPPLIES ON HAND IN OHIO ON OCTOBER 1

Figures 41 and 42 show the expected duration of food supplies in each county for the two dates of attack. The population distribution used in preparing these maps corresponds to the survivors of the attack. It assumes that the population had evacuated according to the Crisis Relocation Plan (described in an earlier chapter) before the attack began and is the same as shown in Figure 18. Again, it is clear from these maps that the western regions of the state have much longer expected duration times for food supplies. The situation is particularly critical in October, when several counties in the southeastern portion of Ohio would be left with less than a month's supply of food.

10. <u>Summary of Stored Food</u>

The above data point out clearly that the season of an attack would have a strong impact on the chances of the population to survive. As has been shown, following an attack on January 1, the expected time that stored food would last is about 2 years. Although some counties would have shortages of food, these local problems could probably be solved if some transportation were available. The 2-year supply of food would give the population time to restart food production before shortages arose on a wide scale.

An attack on October 1, however, would come at a critical time in the food supply schedule. The attack would occur as farmers were preparing to harvest the corn crop. The crop might be lost because the farmers would be unable to go into the fields due to high levels of radiation. The data show that on October 1 there would be only 180 days supply of food. Furthermore, shortages of food in many counties would occur almost immediately. Some counties would run out of food in only a week or two. Thus, the reestablishment of transportation of food would be critical. Furthermore, under these circumstances, the resumption of agriculture also would be critical in order that more food could be produced before the existing supplies were exhausted. The following section discusses the resumption of agriculture and the expected crop yields in the postattack period.

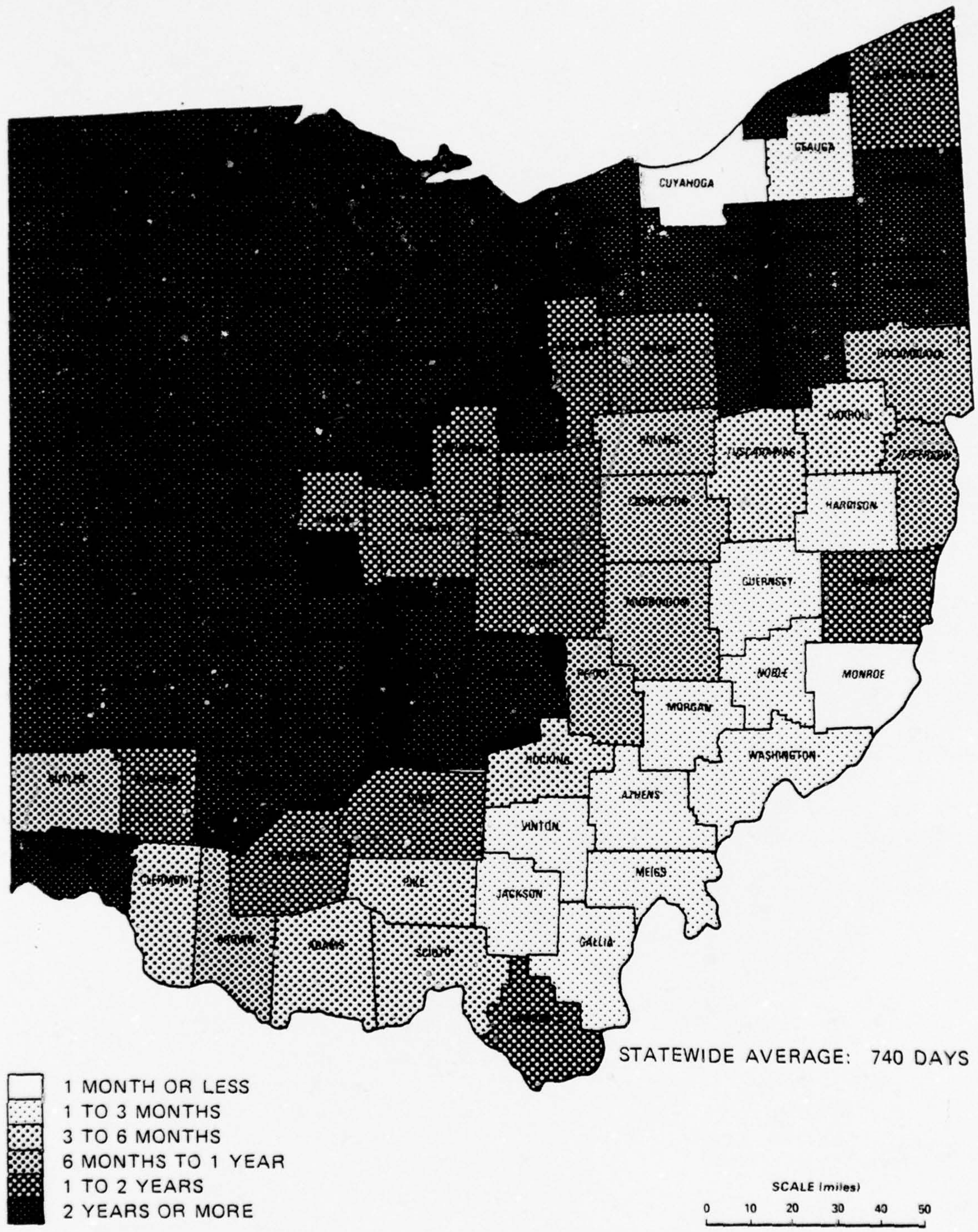


FIGURE 41. DURATION OF POSTATTACK FOOD SUPPLIES ON HAND IN OHIO ON JANUARY 1 FOR SURVIVING POPULATION RELOCATED BY SPC METHOD

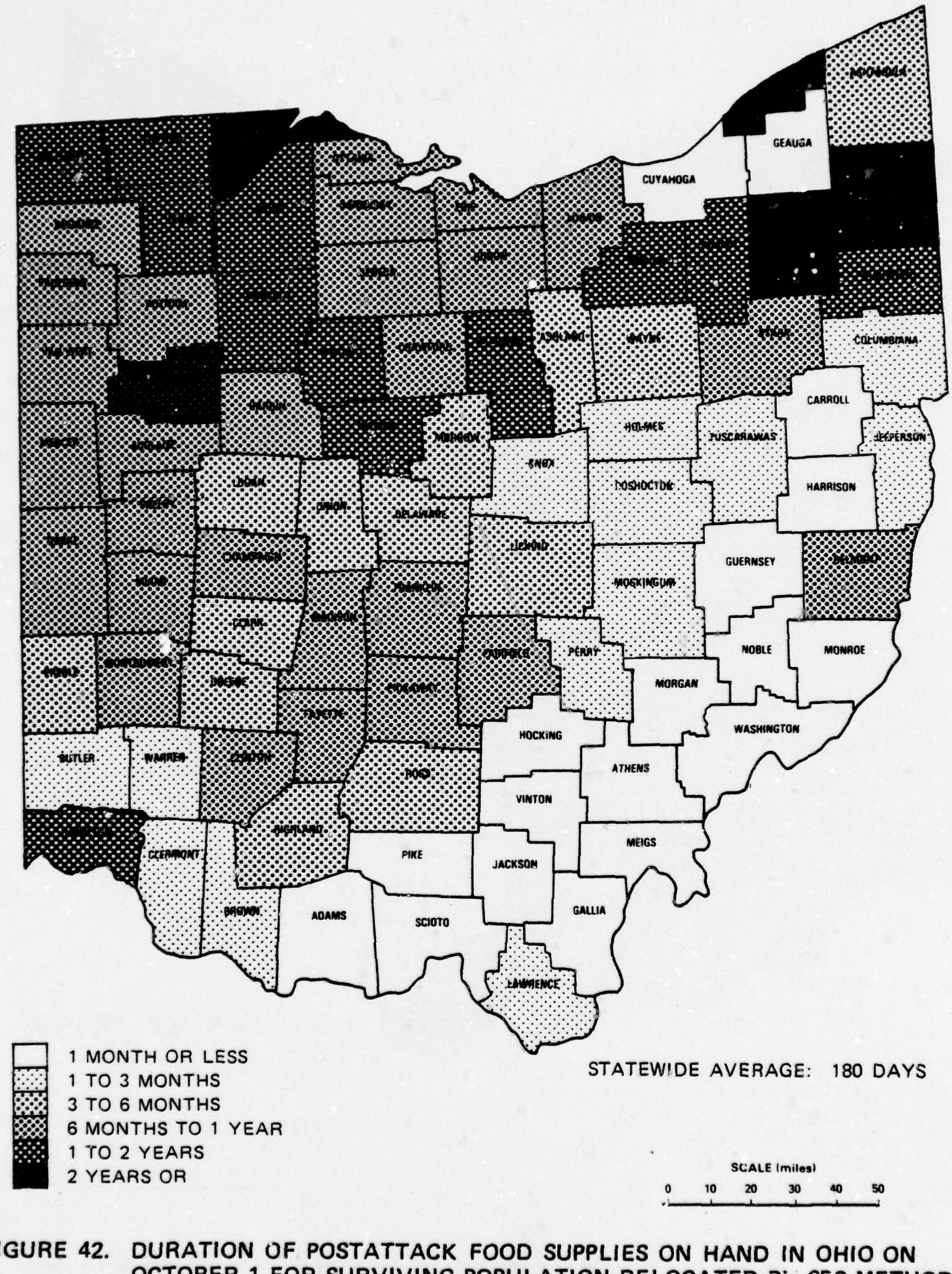


FIGURE 42. DURATION OF POSTATTACK FOOD SUPPLIES ON HAND IN OHIO ON OCTOBER 1 FOR SURVIVING POPULATION RELOCATED BY SFC METHOD

C. AGRICULTURE

1. Introduction

Depending on the season of the attack, food supplies in Ohio could be expected to last from 6 months to 2 years. During this period (i.e., before surviving food stocks were exhausted), agriculture would have to be resumed. The obstacles facing farmers in continuing agricultural production in the postattack period can be divided into two categories: (1) those that depend on the timing of the attack vis-à-vis the crop season, and (2) those that will affect farming regardless of the time of the attack. These obstacles are described in the following two sections.

2. Seasonally Dependent Obstacles

A detailed answer to the question of how farming would begin again immediately after attacks occurring at different times of the year would be extremely complicated and beyond the scope of this report. Such obstacles relate primarily to the interaction of the fallout with crops in the field and would determine what procedures the farmers would need to follow to restart farming. Table 19 shows the gamma dose required to reduce crop yield by 50 percent for corn, wheat, soybeans, and other crops. Since large areas of Ohio receive gamma doses in these ranges, major crop losses would be a distinct possibility. Furthermore, beta radiation would cause additional crop damage. The combined effects of gamma and beta radiation on crops as a function of dose, exposure-rate, crop type, stage of growth, and numerous environmental factors (e.g., moisture, temperature, light, etc.) is quite complicated; the reader is referred to Reference 70 for a fuller discussion. In any case, at certain times of the year, destruction of crops in the field would be greater than at others. In addition, at some times of the year, particularly at harvest, crops could be susceptible to damage (e.g., rotting) if farmers were denied access to croplands until fallout levels diminished to safe levels. Thus, attacks at different times of the year might produce significantly different crop yields for the following harvest.

TABLE 19. GAMMA DOSE IN ROENTGENS TO REDUCE CROP YIELD BY 50 PERCENT[a,b]

Peas Broadbean	Less than 1,000
Rye, Barley, Onion	1,000 - 2,000
Wheat, Corn, Oats, Cucumber	2,000 - 4,000
Peanut, Alfalfa, Fescue, Sorghum	4,000 - 6,000
Cotton, Sugar Cane, Melons, Celery	6,000 - 8,000
Soybeans, Beets, Broccoli, Red Clover	8,000 - 12,000
Rice, Turnips, Sweet Potatoes, Strawberries	12,000 - 16,000
Squash	16,000 - 24,000

[a]Source: References 70, 73.

[b]Beta radiation could cause additional damage (see Ref. 70).

An attack in winter would presumably do the least damage to the crops. The corn and soybeans would not yet be planted, and by spring radiation levels would be safe. The wheat plants would be in the ground, and, although they might suffer some damage, it would probably not be severe. At this time in the year, the crops require the least attention, and so the absence of farm husbandry would not have any serious consequences.

In the spring, an attack could interrupt planting and cause it to be postponed for several weeks. If the attack occurred later in the spring or early summer, radiation damage could be serious. It is possible that replanting of the crops would be the best way to ensure a full harvest in the fall, but this would depend on the availability of seed and on seasonal variables, e.g., rainfall.

Depending on many details [Ref. 70], an attack in summer might or might not result in serious reduction in crop yields from fallout.

By fall, however, a critical period would be reached as harvest approached. Although the plants would be less biologically vulnerable to fallout damage, an attack just prior to the harvest would keep the farmers out of the fields and prevent them from harvesting on schedule. The effect

on the crops would then likely depend on weather. If the crops in the field remained dry, they would probably still be in good condition when the farmers were able to leave their fallout shelters and begin the harvest. On the other hand, rainy weather could result in serious loss of the crops in the field.

In short, the effects of the time of the attack on crop yields are quite complex and dependent in large part on uncontrollable circumstances. Further research in this area would be clearly valuable.

3. Seasonally Independent Obstacles

Modern mechanized agricultural techniques in the United States require large amounts of several inputs such as fuel and fertilizers. Without these inputs, crop yields would be expected to drop significantly [Ref. 72]. In the postattack period, availability of these inputs would be limited. Farmers might have to modify their farming techniques in order to maximize crop yield for the amounts and mixes of inputs that would be available.

The availability of farm machinery should not be a limiting constraint on postattack agriculture. Large numbers of farm machines are located on farms today. Only a small fraction of these machines would be damaged by direct weapons effects since farm equipment is relatively durable, and possibilities for cannibalization would permit repairs and reduce the need for spare parts [Ref. 74]. Rather, fuel availability will likely be the major determinant of the character of postattack agriculture. Fuel for the farm is discussed in the next section. In the following section, other agricultural inputs--fertilizer, pesticides, and seeds--are considered.

a. Fuel

Table 20 shows the amount of fuel used per acre for farming in the United States for the three major crops in Ohio--corn, wheat, and soybeans. Shown with these numbers is the total number of acres of each crop harvested in Ohio annually. In order to maintain preattack levels of mechanization, a minimum of about 160 million gallons of fuel would be necessary for use

in postattack agriculture. This sum includes only those three major crops and makes no allowances for other crops that are currently harvested in relatively smaller amounts in Ohio.

TABLE 20. FUEL REQUIREMENTS FOR AGRICULTURE

	Acres (10^3)	Fuel/Acre (gal)	Fuel (10^6 gal)
Corn	3,800	22.0	84
Wheat	1,600	9.6	15
Soybeans	3,100	19.0	59
Total			158

Source: References 63, 75.

As estimated in Chapter III, immediately after the attack there might be approximately 200 million gallons of fuel available. Because of the expected delay in restoring fuel production, this amount may be the only source of fuel for agriculture. Although the amount of fuel in the state would exceed the amount necessary for agriculture, other uses for fuel, particularly transportation of food and further energy production, would draw on the same supply. Thus, it would be necessary for farmers to conserve fuel as much as possible.

The size of the reductions in crop yields attributable to fuel shortages is uncertain. To some extent, the lack of fuel may be compensated for by an increase in manual labor. Table 21 shows inputs to corn farming for three cases. These are present U.S. techniques, 1945 U.S. farming, and present-day inputs to corn farming in Mexico in regions where farming is still labor intensive. Along with the inputs shown are the related crop yields under these circumstances.

TABLE 21. ANNUAL INPUT AND OUTPUT FOR CORN PRODUCTION PER HECTARE

Input	U.S., 1970	U.S., 1945	Mexico[a] Current
Labor	22 man-hours	57 man-hours	1,144 man-hours
Fuel	206 liters	140 liters	0
Nitrogen	125 kg	8 kg	0
Phosphorus	35 kg	8 kg	0
Potassium	67 kg	6 kg	0
Insecticides	1.1 kg	0	0
Herbicides	1.1 kg	0	0
Seeds	21 kg	11 kg	10.4 kg
Output			
Corn Yield	5,080 kg	2,132 kg	1,944 kg

[a]Regions where agriculture is manual.

Source: Reference 75.

The table suggests that the most significant difference in yields is between current U.S. agricultural production and that in 1945. During the past 30 years, the greatest change in input quantities has not been in fuel consumption but rather in fertilizer use. Fuel consumption per acre increased approximately 50 percent, but nitrogen use increased by 15 times, phosphorous by 3 times, and potassium by 10 times. These increases resulted in about 2.5 times the 1945 crop yield. On the other hand, a comparison between U.S. corn farming in 1945 and Mexican labor intensive corn farming areas reveals that it may be possible to substitute manual labor for fuel. For these two cases, output is roughly the same per acre, although no fuel is used in the Mexican case.

Substitution of labor for fuel might not be easily accomplished in the postattack period, however [Ref. 76]. An early postattack study conducted by the Stanford Research Institute concluded that if an essentially mechanized agricultural system were maintained in the postattack period but farm manpower were doubled to substitute where possible for a 50 percent reduction in fuel, net postattack farm production would increase only 6 percent above the 74 percent of normal production it would have been in the absence of such a substitution [Ref. 76]. Although there would be a large labor pool to draw on among the relocated population, these people would be completely unfamiliar with farm work. Furthermore, modern farms would lack sufficient quantities of the farm implements needed to equip the greatly increased number of farm laborers. As one analyst concluded, "It will not be technologically feasible to achieve [postattack] viability with a drastically more primitive division of labor, involving a large factor increase in the percentage of the population living on farms, unless perhaps this policy is deliberately adopted and prepared for." [Ref. 5] In the absence of such preparation, it would appear that the best way to ensure higher crop production would be a continuation of mechanized techniques to the extent permitted by the amounts of fuel available.

b. Other Inputs

As was shown in Table 21, fuel is only one of several inputs to farming, and the significance of the others in combination may be as great or greater in terms of crop yields. While the influence of fertilizer, pesticide, and seed shortages on postattack crop yield is discussed below, it should be noted that no attempt has been made to predict synergistic effects on crop production.

One of the most important soil nutrients is nitrogen. The nitrogen fertilizer industry is heavily concentrated in Louisiana, Mississippi, and Texas due to the availability of natural gas used in the production of this fertilizer [Ref. 77]. The nitrogen facilities in Ohio are located in three counties: Allen, Hamilton, and Lawrence--all risk counties [Ref. 47]. Thus, fertilizer availability is likely to be extremely limited in the postattack period. Use of animal manure as a substitute for chemical fertilizers would be impossible since there would be so few surviving animals. Even if they were to survive, the energy necessary to transport the manure would be substantially higher than the present energy required in applying the more efficient chemical fertilizers to the land [Ref. 75]. Lack of adequate fertilizer might create a serious decrease in agricultural production in the long run [Ref. 61]. However, for the first year after the attack, the lack of fertilizers might not critically reduce yields. In part, this would be due to the residual fertilizers, particularly phosphorus and potassium, left in the soil from the last preattack applications.

Lack of adequate weed control for corn and soybeans could produce major reductions (i.e., 20 to 90 percent) in the yields of these crops.[1] Clearly, the absence of chemical herbicide applications would increase the likelihood of such large crop losses. However, herbicide shortages in the postattack period could be compensated for with increased mechanical cultivation, or to minimize farm fuel consumption, increased manual weeding [Ref. 47].

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[1]Unless otherwise noted, information concerning pesticides has been taken from Reference 77.

Plant disease control presently is accomplished through cultured practices, genetic resistance, and chemical treatments. Without continued implementation of preattack control practices, plant diseases could cause losses (i.e., 10 to 35 percent) in the corn crop. However, the probability of severe losses across the entire corn crop is not high because the effects of diseases tend to be localized. Soybean diseases might also cause significant crop losses, but such diseases would probably not reach epidemic proportions in the first year.

Approximately 50 to 60 percent of corn acreage is treated with some insecticide every year. Although annual applications have increased markedly in recent years, soybean insecticide treatment compared with corn is relatively limited. A large amount of the insecticide used on corn often turns out, in retrospect, to have been unnecessary. This is due to the uncertainty confronting farmers in predicting the magnitude of the insect problem at the time the crop is planted. Nonetheless, without effective controls (e.g., insecticides), corn crop losses might be as high as 50 percent in special local areas, although no greater than 35 percent for the state as a whole. Soybean insects could also cause major soybean losses; however, losses would in general be smaller than those suffered by the corn crop. Furthermore, if more effective crop rotation were planned, it would help in controlling pests, while reducing the need for pesticides [Ref. 75].

Commercial seeds for planting hybrid crops are a characteristic input to modern farming. Farmers usually purchase seeds to be planted rather than producing them on the farm. Seed stocks tend to be located with farm operations, and thus would not likely be damaged by an attack [Ref. 74]. Previous research suggests that, for the country as a whole, surviving commercial "seed supplies would be adequate for sowing available cropland in the first postattack year." [Ref. 74] Were commercial seeds unavailable in the postattack period, it would be possible for farmers to divert needed seed from overall crop production. Only 3 percent or less of the wheat, corn, and soybean crops would need to be diverted for seed [Refs. 65, 75].

Seed harvested from farmers' fields of hybrid corn generally would yield 15 to 20 percent less than a crop planted with new hybrid seed. Because soybeans are a self-pollinated crop, soybean seed harvested by a farmer could be replanted without loss in yield [Ref. 75].

3. Summary

The obstacles to resumption of agricultural activities following an attack have only been sketched here. The state of postattack agriculture in Ohio cannot be predicted with any great confidence. Multiplicity of inputs, varying conditions, and possible synergistic effects complicate the analysis. However, some bounds can be placed on the extent of obstacles to postattack agriculture.

For the first year, fertilizer shortages might not be critical, although if fertilizer shortages persist the long-run outlook would be more pessimistic. Similarly, lack of pesticides alone most probably would not result in major crop losses if compensating countermeasures are adopted. Even if no commercial seeds were available, decreases in yields produced by the absence of this input would be relatively minor.

Fuel supplies for agricultural use would likely be marginal. Substitution of manual labor for machine operations might be possible, although not preferable to continued mechanized agriculture. Postattack crop yields would decline but probably not significantly below the level of present-day Mexican labor-intensive agriculture. Crop production, then, might be reduced to approximately half of preattack standards. However, Ohio currently produces more than a 2-year supply of food for its population each year. Therefore, despite disruptions and severe input shortages in the agricultural sector in the wake of an attack, the state would probably be able to feed its population at a basic level if surviving resources are carefully managed.

VI. WATER

A. THE PROBLEM OF RADIOACTIVE CONTAMINATION OF POSTATTACK WATER SUPPLIES

A minimal supply of potable water is essential for human survival under any conditions. Following a nuclear attack against the United States, surface waters (i.e., streams, lakes, and reservoirs) in the path of fallout clouds would become contaminated to varying degrees by radioactive fission products. Ingestion of these radioactive nuclides[1] by the drinking of contaminated water could constitute an important health hazard in the early postattack period. Groundwater (i.e., water from wells and springs), on the other hand, would be relatively free from radioactive contamination because the ground mantle would significantly impede the seepage of surface-deposited fallout into underground water sources.

This chapter attempts an answer to the question of whether postattack potable water supplies would be sufficient to meet the survival needs of the relocated population in Ohio. It is a relatively conservative analysis, which pursues increasingly stringent assumptions to suggest, in the end, that the postattack problem of radioactive contamination of water supplies should be a manageable one. Minimal water consumption requirements are first defined. The postattack availability of rural domestic and host county municipal groundwater supplies is then assessed. Difficulties in groundwater withdrawal in the absence of an offsite source of electricity are addressed. Because it might be possible that some of the relocated population would not have ready access to groundwater, a simple technique is described for making

[1]Iodine-131, stronium-89, stronium-90, cesium-137, barium-140, and ruthenium-106 would be the elements most hazardous to body organs [Ref. 78].

contaminated surface water relatively safe. Also described is the administration of potassium iodide to prevent iodine-131-induced thyroid damage. In the final section, the assumption is made that none of the above precautions were observed. The "worst case" in terms of the contamination hazard is then examined.

B. MINIMAL WATER CONSUMPTION REQUIREMENTS

The minimal daily water intake required for an inactive man under conditions where no sweating occurs is about 1.1 quarts. Physical work induces sweating and thus raises the level of water intake needed to maintain a normal state of body hydration. As a general rule, the minimal water requirement is that amount which will allow for urine excretion of somewhat less than a quart daily [Ref. 79]. In addition to water for drinking, water would be needed, at a minimum, for washing and cooking. As a planning number, 4 to 5 gallons of water per person per day should be adequate in the first postattack year for drinking, washing, and cooking [Refs. 80 and 81].

C. AVAILABILITY AND ACCESSIBILITY OF GROUNDWATER IN OHIO

Exclusive reliance upon groundwater for drinking in the first several weeks postattack would be an important means of circumventing the hazard posed by postattack radioactive contamination of water supplies. Therefore, likely available postattack groundwater supplies in Ohio were analyzed.

1. Availability of Groundwater

Table 22 depicts estimates of rural domestic and municipal groundwater supplies in the counties in Ohio following population relocation and an attack. Private wells constitute the rural domestic water supply. They would be generally undamaged by direct weapons effects. Most counties would have 3 or more gallons of groundwater per person per day, thus meeting the drinking requirement, but not in all cases meeting the 4 to 5 gallons standard, which also includes washing and cooking.

TABLE 22. POTENTIAL POSTATTACK PER CAPITA GROUNDWATER SUPPLIES IN OHIO

County	Groundwater Per Capita Per Day (gal)			County	Groundwater Per Capita Per Day (gal)		
	Rural Domestic	Municipal	Total	County	Rural Domestic	Municipal	Total
Adams	3.0	4.5	7.5	Licking	13.0	50.3	63.3
Allen	55.2	R	55.2	Logan	3.0	15.8	18.8
Ashland	5.0	11.6	16.6	Lorain	248.4	R	248.4
Ashtabula	23.8	14.3	38.1	Lucas	0	R	0
Athens	0.7	13.1	13.8	Madison	3.0	67.8	70.8
Auglaize	4.4	15.8	20.2	Mahoning	414.4	R	414.4
Belmont	33.8	R	33.8	Marion	5.1	16.6	21.7
Brown	4.2	1.4	5.6	Medina	96.4	R	96.4
Butler	4.2	40.6	44.8	Meigs	0.8	3.2	4.0
Carroll	5.3	2.7	8.0	Mercer	4.7	3.1	7.8
Champaign	3.2	9.6	12.8	Miami	11.0	18.0	29.0
Clark	2.4	59.7	62.1	Monroe	2.2	1.1	3.3
Clermont	4.5	20.4	24.9	Montgomery	3.4	R	3.4
Clinton	3.4	1.7	5.1	Morgan	3.8	6.3	10.1
Columbiana	8.5	3.3	11.8	Morrow	5.2	5.2	10.4
Coshocton	3.1	16.0	19.1	Muskingum	4.7	24.3	29.0
Crawford	4.3	3.4	7.7	Noble	2.9	NA	2.9
Cuyahoga	0	R	0	Ottawa	5.3	10.7	16.0
Darke	5.7	3.4	9.1	Paulding	3.4	1.7	5.1
Defiance	5.2	2.6	7.8	Perry	9.5	1.6	11.1
Delaware	4.7	1.6	6.3	Pickaway	5.5	8.6	14.1
Erie	0	5.9	5.9	Pike	2.4	3.2	5.6
Fairfield	1.7	36.6	38.3	Portage	2,500.0	R	2,500.0
Fayette	3.4	0.9	4.3	Preble	4.9	4.9	9.8
Franklin	30.2	R	30.2	Putnam	4.3	2.8	7.1
Fulton	13.3	11.4	24.7	Richland	66.7	R	66.7
Gallia	2.2	5.9	8.1	Ross	3.0	7.6	10.6
Geauga	17,000.0	7,000.0	24,000.0	Sandusky	0.9	8.5	9.4
Greene	16.8	28.3	299.8	Scioto	4.6	2.9	7.5
Guernsey	2.6	1.3	3.9	Seneca	2.5	1.3	3.8
Hamilton	8.4	R	8.4	Shelby	4.2	6.8	11.0
Hancock	3.9	0.6	4.5	Stark	180.5	R	180.5
Hardin	3.0	5.2	8.2	Summit	1,347.8	R	1,347.8
Harrison	3.7	0.9	4.6	Trumbull	1,041.7	R	1,041.7
Henry	4.6	2.3	6.9	Tuscarawas	3.6	17.7	21.3
Highland	1.3	4.4	5.7	Union	3.2	2.4	5.6
Hocking	3.3	5.8	9.1	Van Wert	3.4	0.8	4.2
Holmes	4.9	2.4	7.3	Vinton	3.2	0	3.2
Huron	3.0	0.8	3.8	Warren	9.0	22.6	31.6
Jackson	1.6	0	1.6	Washington	3.8	9.2	13.0
Jefferson	40.0	R	40.0	Wayne	7.6	18.3	25.9
Knox	3.9	12.4	16.3	Williams	8.3	33.1	41.4
Lake	5,714.3	R	5,714.3	Wood	15.8	1.6	18.4
Lawrence	139.2	R	139.2	Wyandot	3.4	2.6	6.0

R = Risk county NA = Not available

Source: U.S. Geological Survey, Water Resources Division, District Office, Columbus, Ohio, April 1979.

In the second column, municipal groundwater supplies are shown. For risk counties, where municipal facilities would probably be inoperable after the attack, no supplies are shown. Only the 39 percent of municipal groundwater currently consumed by households was assumed available for drinking [Ref. 82]. This is a fairly strict assumption, reflecting the belief that water diverted to industrial and commercial uses might be inaccessible for drinking, washing, or cooking purposes. Of course, presently only half of the household water supply is used for drinking, washing, and cooking; the other half is used in flushing toilets, watering lawns, washing cars, and general cleaning. However, it seems reasonable to assume that in the postattack period all household water could and would be used only to meet survival needs [Refs. 82-84].

Even if only a very small fraction of preattack supplies were available, those supplies, combined with rural domestic groundwater, would be sufficient in all cases to meet drinking requirements, and adequate in nearly all cases to fulfill washing and cooking needs as well. This is indicated by the data on total groundwater available shown in Table 22 and depicted in Figure 43.

2. Accessibility of Groundwater

Clearly, there should be enough groundwater to fulfill the survival needs of the relocated population in Ohio. That is, sufficient water should be available _if_ it can be withdrawn from the ground. The problem of accessibility in addition to availability must be addressed.

a. Restoring Existing Systems

Pumps are used to draw water from underground aquifers. Nearly all pumps--both those of municipal pumping stations and those of small, domestic wells--are powered by electricity. Loss of electric power in the wake of the damage done by an attack (combined with direct damage to water utility bulidings and the water distribution network) would cause the loss of water pressure and the loss of water flow. Thus, the question arises: Can groundwater be withdrawn without an offsite supply of electricity to the pumps?

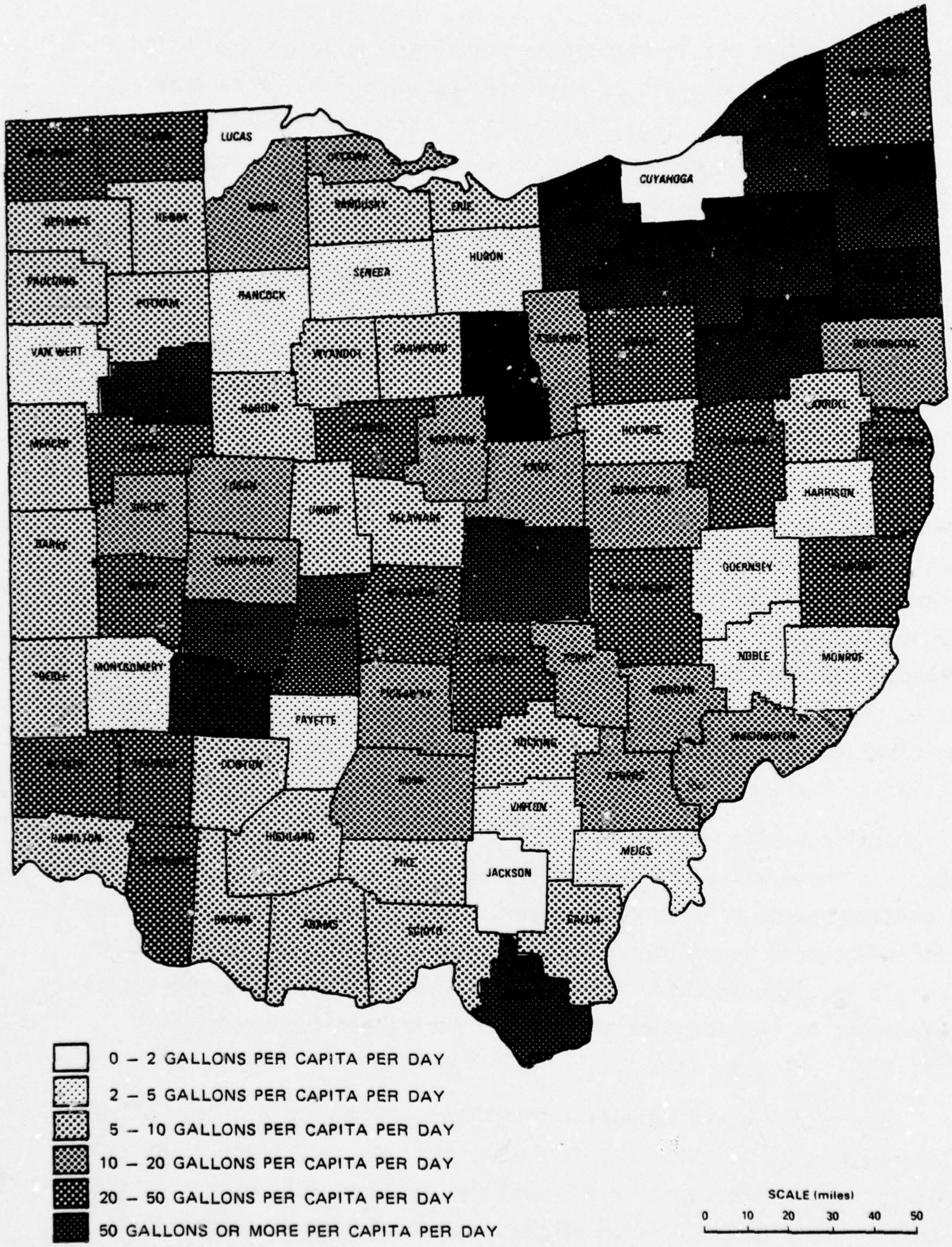


FIGURE 43. POTENTIAL POSTATTACK GROUNDWATER SUPPLIES IN OHIO

Under current crisis relocation planning, the large population in high-risk urban areas would be evacuated to lower-risk, more sparsely populated rural areas. Thus, following an attack, rural municipal water facilities would be a major source of water. About 95 percent of all rural residents are served by groundwater sources [Ref. 85]. Most rural facilities would be relatively undamaged because of their location outside of likely blast zones. Less than 10 percent of these facilities have onsite emergency generators. However, because they require less energy to operate than do water systems in large cities, offsite generators could be brought in to provide power for rural facilities. Local civil defense officials generally have some knowledge of where generators held by the National Guard and county government and those owned by private citizens are located.

In the postattack period, given the increased demand for rural municipal water caused directly or indirectly by the attack, all available water would have to be carefully rationed. Survivors might queue up to the nearest water facility for their daily minimal ration (plastic bags perhaps could be stockpiled at the facilities in peacetime for postattack use as reusable containers), or tank trucks powered by gasoline from municipal supplies might be used to distribute the water to the postattack population [Ref. 86].

Rural domestic wells would also provide a source of groundwater. The pumps for these wells are driven by electric motors. In the absence of an outside source of electrical power, these pumps could be run by small gasoline-powered generators commonly found on farms. It would also be possible to withdraw water from domestic wells using a rope-and-bucket arrangement or perhaps more accurately, string-and-cup arrangement [Ref. 87].

None of the above expedient techniques would ensure a rate of water withdrawal comparable to that in peacetime. However, these calculations indicate that, under austere survival requirements, the rate of withdrawal need only be a small fraction of that preattack, and it seems likely that this need could be met.

Finally, it should be noted that all of the above techniques (with the exception of the rope-and-bucket arrangement) assume the availability of the gasoline required to fuel the generators. Gasoline will be extremely scarce in the postattack period. Because of water's preeminent importance to survival, the allocation of gasoline to groundwater supply generators should be accorded a high, if not the highest, priority.

b. Digging Additional Wells

If, for whatever reasons, groundwater could not be drawn from existing sources, new wells might be dug employing relatively primitive techniques and available materials. Two recent handbooks, dealing with the problems of inadequate water supplies in the developing countries, provide detailed descriptions of simple water well technologies for supplying drinking and domestic water to small communities. The technologies seem very applicable to the postattack environment. The wells described in the handbooks are intended "not for highly sophisticated societies, nor for those interested in the normal, capital-intensive techniques of well-drilling." [Ref. 88] The description contained in one of the handbooks of the type of wells contemplated makes them sound ideally suited to post-attack conditions:

> The manual describes hand-dug shaft wells and their construction by relatively unskilled villagers. Modern concepts, methods, and designs are incorporated, but in such a way that those who will carry out the actual work do not require a high degree of education, training or supervision. Much of the equipment can be made locally and costs (especially the cost of imported materials) can be kept to a minimum. The simple directions are based upon proven methods and satisfactory results gathered from various parts of the world. Wells constructed by the methods indicated need be in no way inferior to those produced by mechanical equipment at many times the expense. They can be as reliable, as versatile, as adaptable to varying conditions and they can yield as much water of as high a quality even though they may not be capable of being constructed so quickly [Ref. 89].

Needless to say, as is the case with many civil defense measures, the actual as opposed to potential effectiveness of expedient well construction will depend upon the information available to survivors and the existence of a postattack "government" for organizing their collective efforts.

D. A SIMPLE WATER DECONTAMINATION TECHNIQUE

In many localities after an attack, it may be impossible for the population to rely exclusively upon underground sources for potable water. Civil defense planners should be prepared for this contingency. Simple means have been developed for removing radioactive fallout material from contaminated (e.g., surface) water. One such method was tested in the early 1960s by the U.S. Army Engineering Research and Development Laboratories [Ref. 90]. The technique involves a filter made of a flowerpot (or a tin can, aluminum foil, newspaper, etc.), toilet tissue, a piece of screening, and a 5-cm column of subsoil. This filter removed 93 to 99 percent of the radioactivity from well water highly contaminated by nuclear bomb debris from the AEC's Nevada Test Site. The "flowerpot procedure," then, offers a simple and practical means of removing radioactivity from contaminated water to produce a potable supply of water under emergency conditions.

E. POTASSIUM IODIDE AS A POSSIBLE PROPHYLACTIC

Radioiodine (iodine-131) is difficult to remove from contaminated water using soil as a filter [Ref. 90]. Yet the ingestion of I-131 by children poses perhaps the greatest health hazard created by radioactive contamination of drinking water supplies. Absorption by the thyroid of I-131 can produce serious thyroid injury, particularly in children. In 1954, 64 inhabitants of the Marshall Islands unknowingly were exposed to fallout radiation from a nuclear weapon test. Many of the Marshallese drank contaminated water and ate contaminated food for up to 2 days.

Since 1954, the overall health of the exposed adults has been good. However, by 1974, thyroid abnormalities had been detected in 28 people. Twenty-two of those individuals had thyroid lesions. Of those with lesions, three had malignancies and two had hypothyroidism. Most of the thyroid problems were suffered by those who were less than 10 years old at the time of the test [Ref. 16].

A saturated solution of potassium iodide (SSKI) has been shown to be an effective blocking agent against absorption of radioiodine by the thyroid [Ref. 91]. SSKI would be a possible countermeasure for mitigating the I-131 hazard following a nuclear attack.

During the Three Mile Island incident in spring 1979, a large pharmaceutical firm (under an FDA order) produced 237,000 1-ounce bottles of SSKI in a 4-day period. Given the labeled daily dosage of two drops for adults and children and one drop for infants, each bottle was calculated to provide 450 person-doses or would supply 45 people for 10 days [Ref. 92].

At the stated rates of administration, the total supply contained 107 million person-doses, enough for 3.6 million people for 30 days, or 10 million people (the present population of Ohio) for 10 days. The SSKI supply could have been stretched by only administering the drug to children, for whom radioiodine danger would have been greatest. Moreover, after 10 days of the iodide regimen, an "escape effect" takes place which precludes the thyroid from retaining additional doses of SSKI. Administration of the drug must be temporarily discontinued for several days [Ref. 93].

Actions taken during the Three Mile Island incident indicate that civil defense planners might wish to consider "surge" production of SSKI during the crisis period likely to precede a large-scale attack. In that event, SSKI should probably be produced in quantities just large enough to provide protection for children, the population group at highest risk.

F. SEVERITY OF THE CONTAMINATION HAZARD IN THE ABSENCE OF COUNTERMEASURES

Rather than attempting to define a "safe" level of radioactive contamination of water, the above discussion has suggested countermeasures to the contamination problem, assuming that any radioactivity in drinking water is to be avoided. Nonetheless, following an attack there certainly would be many locales where such precautions could not or would not be taken. Therefore, the "worst case" should be considered; i.e., the consequences for the health of the postattack population from drinking contaminated water.

One view of the "worst case" was presented in a report done by the Stanford Research Institute (SRI) several years ago [Ref. 94]. A hypothetical large-scale (12,000-MT) nuclear attack directed against U.S. counterforce as well as urban-industrial targets was considered. Probable radionuclide concentrations from fallout falling directly on the surface water supplies of various U.S. communities were calculated. Absorbed dosages to the thyroid, lower large intestine, bone, and total body for ingestion of contaminated water from the 1st to the 183rd day after the attack were predicted. The study concluded that

> ...no serious biological effect in adult humans would be expected from consumption of the most highly contaminated water (even without the benefit of decontamination by normal water treatment methods). The probable exception of this conclusion for the entire population is for the thyroid doses to young children. ...continued consumption of water contaminated [with I-131 at the levels produced by a large-scale attack] would result in (at least) partial destruction of children's thyroids [Ref. 94].

The report also argues that the "biological effects arising from drinking surface waters that were contaminated by fallout...would generally be insignificant compared with other [postattack] hazards [e.g., external radiation]."

Although the SRI study minimizes (perhaps correctly) the water contamination hazard, it would seem only prudent, in light of the large uncertainties involved, to give serious consideration to the countermeasures mentioned above. In this regard, note that the report again highlights the radioiodine threat to children's thyroids.

G. SUMMARY

While the radioactive contamination of water supplies <u>may</u> represent a minor danger <u>relative</u> to other postattack threats to life and health, it nevertheless is a hazard deserving consideration of possible countermeasures. Reliance upon groundwater in the early postattack period is one way of minimizing the contamination problem. If pumps could be powered through the expedient use of generators, or new wells dug, sufficient potable groundwater should be available and accessible for survivors in the initial recovery period. Use of the "flowerpot" decontamination filter and administration of SSKI to children would further reduce the radioactive danger. All in all, then, the postattack problem of radioactive contamination of water supplies would appear to be a manageable one.

VII. HOUSING, CLOTHING, AND SANITATION

A. HOUSING

The Crisis Relocation Plan would call for all evacuees to be housed in public buildings in the host counties. No host-area resident would be required to share his home with evacuees, although polls show that 73 percent of people say that they would be willing to admit some evacuees to their homes in a crisis [Ref. 11]. On the other hand, it is not clear how this situation would develop if a large-scale attack occurred, cities were devastated, and the evacuees became semi-permanent residents of the host areas.

Evacuees would be instructed to upgrade the fallout protection factor (PF) of their buildings to 50 or better, by shoveling or otherwise piling earth on the sides or tops. DCPA/FEMA has conducted field tests indicating the feasibility of this procedure [Ref. 95]. Figure 44 illustrates how the fallout protection of a school building could be upgraded during a crisis [Ref. 10].

FEMA maintains the National Shelter Survey, a record of existing fallout shelter space throughout the U.S. FEMA is also in the process of surveying space in potential host areas which, although it does not currently provide PF >40, could be upgraded during a crisis to provide such protection. Ten square feet per person is assumed; this is crowded by preattack standards but is considerably less than many historical examples of conditions where people have been crowded but survived for many weeks [Ref. 73].

Table 23 and Figure 45 summarize data regarding upgradable and NSS (PF $\geq$ 40) shelter spaces in Ohio for nonrisk counties. The map shows the ratios of shelter spaces to final population (not just evacuees). The survey has been completed for only about 45 percent of the nonrisk counties.

An existing school building can serve as a congregate care facility for risk area evacuees. The best fallout protection can be found in interior corridors and rooms on the lowest floor, especially if the school has two or more stories and the exterior walls are of concrete or masonry construction. Fallout protection can be improved by first expediently constructing a wood support wall at the mid-span point and then providing additional vertical and horizontal barriers of earth as shown in sketches. Windows in exterior walls that are to be covered with earth should be protected with lumber or plywood sheets so that they will not break under the earth fill.

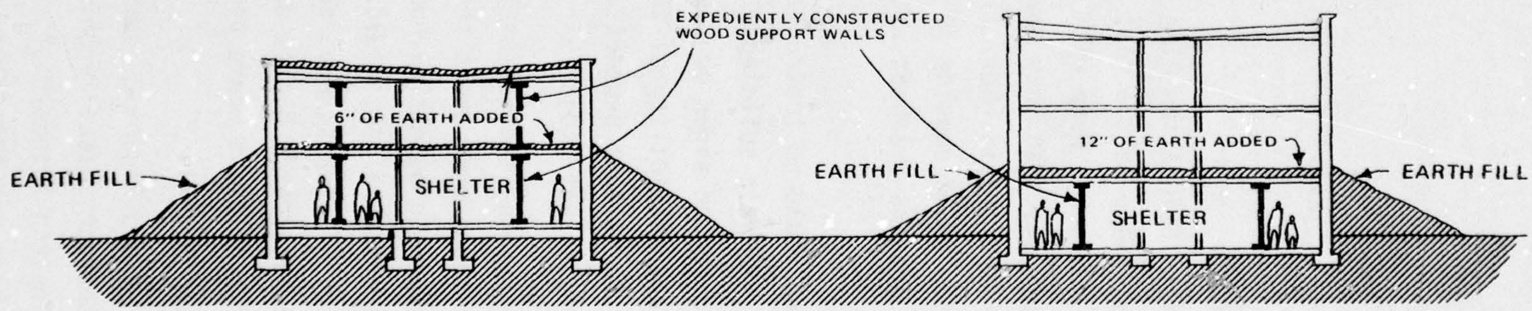


FIGURE 44. FALLOUT PROTECTION IN SCHOOL BUILDINGS

TABLE 23. UPGRADABLE SHELTER SPACES IN OHIO, BY COUNTY

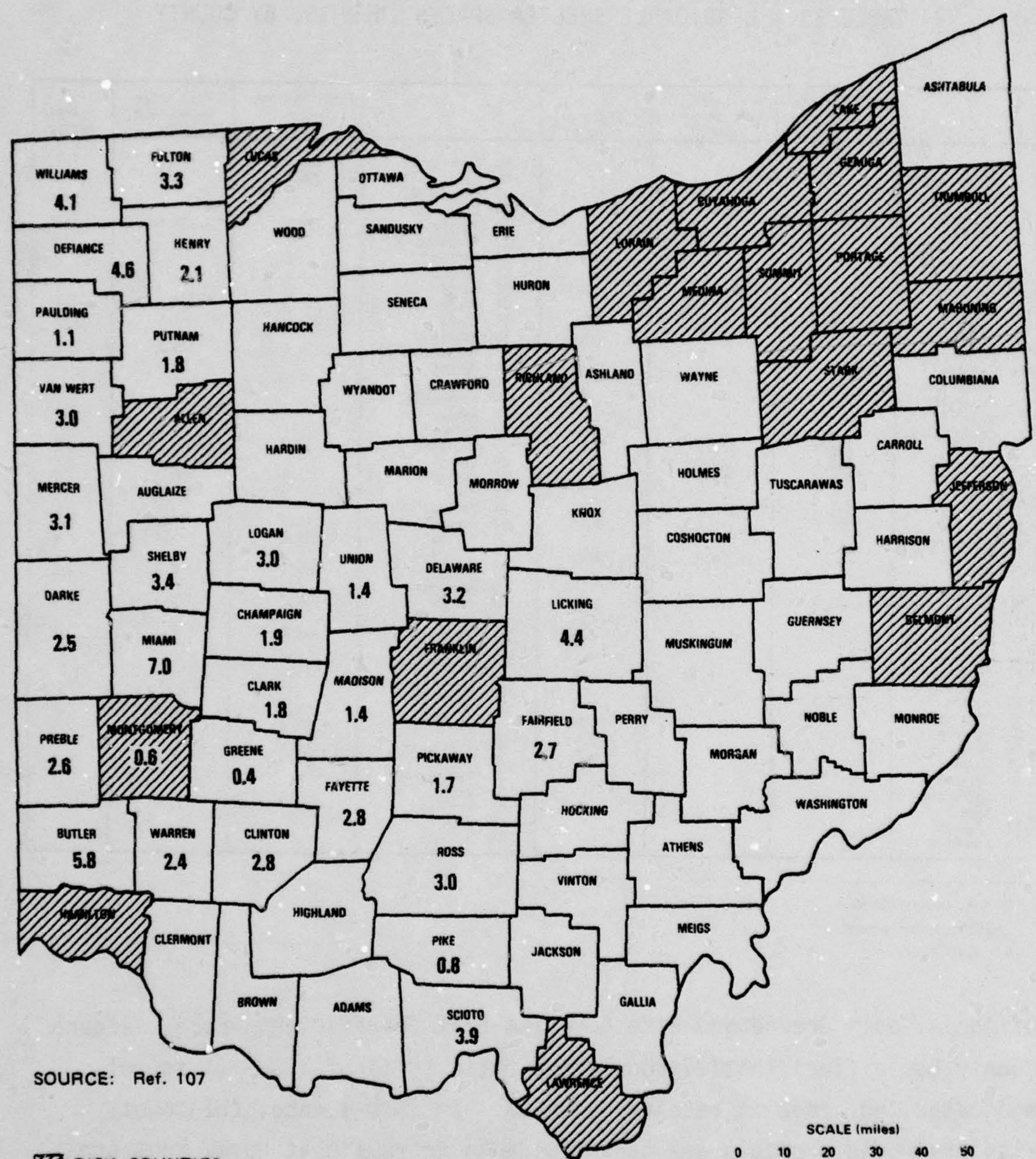
	Total Shelter Spaces[1] 1000s	Pop. After Relocation[2] 1000s	Spaces/ Person		Total Shelter Spaces 1000s	Pop. After Relocation 1000s	Spaces/ Person
1 Adams				45 Licking	873.8	197.9	4.4
2 Allen (R)[3]				46 Logan	398.7	132.7	3.0
3 Ashland				47 Lorain (R)			
4 Ashtabula				48 Lucas (R)			
5 Athens				49 Madison	186.0	133.6	1.4
6 Auglaize				50 Mahoning (R)			
7 Belmont (R)				51 Marion			
8 Brown				52 Medina (R)			
9 Butler	1,420.0	246.0	5.8	53 Meigs			
10 Carroll				54 Mercer	393.5	128.1	3.1
11 Champaign	234.8	124.6	1.9	55 Miami	825.0	117.4	7.0
12 Clark	278.6	151.6	1.8	56 Monroe			
13 Clermont				57 Montgomery (R)	74.8	116.5	0.6
14 Clinton	334.3	118.3	2.8	58 Morgan			
15 Columbiana				59 Morrow			
16 Coshocton				60 Muskingum			
17 Crawford				61 Noble			
18 Cuyahoga (R)				62 Ottawa			
19 Darke	434.3	174.5	2.5	63 Paulding	133.9	118.8	1.1
20 Defiance	550.5	118.9	4.6	64 Perry			
21 Delaware	418.7	129.8	3.2	65 Pickaway	245.4	145.4	1.7
22 Erie				66 Pike	101.4	125.4	0.8
23 Fairfield	388.9	145.7	2.7	67 Portage (R)			
24 Fayette	326.2	116.5	2.8	68 Preble	314.2	123.2	2.6
25 Franklin (R)		-		69 Putnam	255.9	140.2	1.8
26 Fulton	388.5	117.4	3.3	70 Richland (R)			
27 Gallia				71 Ross	596.0	198.2	3.0
28 Geauga (R)				72 Sandusky			
29 Greene	55.8	130.0	0.4	73 Scioto	687.7	175.4	3.9
30 Guernsey				74 Seneca			
31 Hamilton (R)				75 Shelby	402.6	117.7	3.4
32 Hancock				76 Stark (R)			
33 Hardin				77 Summit (R)			
34 Harrison				78 Trumbull (R)			
35 Henry	253.7	120.0	2.1	79 Tuscarawas			
36 Highland				80 Union	178.0	125.2	1.4
37 Hocking				81 Van Wert	354.8	118.0	3.0
38 Holmes				82 Vinton			
39 Huron				83 Warren	278.6	117.7	2.4
40 Jackson				84 Washington			
41 Jefferson (R)				85 Wayne			
42 Knox				86 Williams	501.9	121.4	4.1
43 Lake (R)				87 Wood			
44 Lawrence (R)				88 Wyandot			

[1]PF 40+; 10 ft^2/Person

[2]SPC Relocation Method

[3]R = Risk County

Of these, only Greene and Pike Counties have insufficient space. Greene County has a final/initial population ratio (F/I) of 1.0. It is not evacuated, nor does it receive evacuees. In such a case, the county planners would probably ask many residents to remain at home, thus presumably mitigating the fact that the ratio of spaces in public buildings to the population is only 0.4. For Pike County, this ratio is 0.8, whereas F/I = 6.0. Thus, the ratio of spaces to evacuees is 0.96, which seems sufficiently close to 1.0 to permit the state and county planners to accommodate the evacuees with only minor changes in the overall plan.



SOURCE: Ref. 107

RISK COUNTIES

NUMBERS INDICATE THE RATIO OF AVAILABLE SPACES IN PUBLIC BUILDINGS TO THE FINAL POPULATION (RESIDENTS PLUS EVACUEES)

FIGURE 45. SHELTER SPACES PER PERSON IN OHIO (Existing and upgradable)

The conclusion is that availability of upgradable and NSS (PF $\geq$ 40) shelter space will not impose a significant constraint on the workability of the relocation.

If the attack occurred and the evacuees had to remain in the host areas for a year or more, undoubtedly many people would readjust their living arrangements during the first several weeks. Nevertheless, the average density of people per room would increase to 2 to 4 times its present value. This would certainly be inconvenient by preattack standards, but would still be less than current conditions in some Less Developed Countries (LDCs) (see Table 24).

TABLE 24. HOUSING SPACE IN VARIOUS COUNTRIES

Place	Persons per Room	Relative to U.S.
United States	0.6	1.0
Canada, United Kingdom	0.7	1.2
France, West Germany	0.9	1.5
Puerto Rico, Italy	1.1	1.8
Czechoslovakia, Finland	1.3	2.2
Soviet Union, Greece	1.5	2.5
Poland, Yugoslavia, China	1.7	2.8
India, Guatemala	2.6	4.3
Bangladesh	3.2	5.3

Sources: References 73, 96.

B. CLOTHING AND BEDDING

The Crisis Relocation Plan would not include any Government-supplied clothing or bedding. Evacuees should be instructed to bring warm clothing and bedding, especially sleeping bags (if they own any), with them regardless of the season of the attack, lest they have to live for a year or more in unheated buildings.

The use of scarce supplies of energy to heat buildings might well be the exception (hospitals, nursing homes, etc.) rather than the rule in the postattack environment. If so, then in winter, people would have to wear coats even while indoors during the day. At night, people without good sleeping bags would have to wear coats, heavy underwear, etc., and cover themselves with as many blankets as they had. However, survival under such conditions is straightforward and routine in many parts of the world. It is recommended that, as part of peacetime education programs, the public be advised as to the merits of purchasing sleeping bags capable of protecting them against low temperatures for emergency preparedness.

C. SANITATION[1]

Most rural water and sewer systems will survive the attack. The required electric power, or other energy supplies, may be available to operate some of them. In areas where municipal sewer systems are not available, primitive sanitation methods, such as those used today in some LDCs, might have to be used.

The 1975 Health Sector Policy Paper of the World Bank [Ref. 97] points out that on the average, for countries with a per capita income of less than $100/year, in rural areas 13 percent of the people have "reasonable

[1]Several studies of postattack sanitation have been performed by Engineering-Science, Inc. [Refs. 98-101]. However, they are not very appropriate as inputs to the present study because they concern urban environments exclusively.

access" to water supply (only 3 percent in rural Pakistan), and only 7 percent have "adequate" access to sewage disposal. Reference 97 describes the situation as follows (pp. 19-22):

> Rural populations in the poorer developing countries have access to almost no sewage disposal facilities. In urban areas, there is considerable reliance on buckets, pit privies and septic tanks which are not connected to a public sewer system. Facilities connected with the city sewer systems are not widespread, except in the higher-income developing countries.[1]
>
> In most countries, only a small proportion of the rural population has access to modern water systems. In the urban areas of countries with per capita incomes below $150, roughly a third of the population depends on public standposts, and only the middle- and higher-income groups use more sophisticated facilities. A substantial part of the population--rural and urban--relies on polluted river water, or similar sources.
>
> ⋮
>
> Relatively simple techniques of waste and water treatment are available which, if applied, would greatly diminish the risks of catching fecally-transmitted disease. Sanitary storage of human excreta accomplishes a great deal; within two weeks, many of the harmful bacteria die because they cannot survive for long outside the human host. Viruses are also delicate organisms and can be expected to die quickly. Helminths can remain a hazard for a longer period of time, particularly in the form of resistant cysts; eventually the cysts also die. Another technique of waste disposal is sedimentation or filtration. In both cases, the solid particles to which bacteria cling are separated out and retained till harmless. In addition, two decomposition processes, which occur naturally, render sewage harmless: oxidation (using oxygen from air or water) and anaerobic fermentation. Which of the two processes occurs depends upon the availability of oxygen for oxidation. Many "modern" processes, such as trickling filters and aeration, are simply intended to speed the natural process. Most decomposition processes rely on successive biological cycles which involve different algae. During the course of these cycles,

---

[1] In LDCs, human solid waste is frequently used for fertilizer (night soil).

> organisms that are harmful to man are destroyed. Even helminths may be killed by the heat generated by a composting system of anaerobic fermentation. If at all possible, a biologically pure source of water should be chosen. If not, processes such as storage and sedimentation-filtration should be employed. Chemical treatment by chlorination of water is also highly effective in destroying a wide variety of disease agents. [Emphasis added].

Given these considerations, it would appear that sanitation would be a tractable problem in postattack rural Ohio, where, even after relocation, the rural population density would still be several times less than that in some LDCs.

This conclusion is consistent with the results of "Environmental Health Planning for Postattack Conditions," a study conducted in 1966 by Research Triangle Institute, which concluded:

> Sewage treatment and disposal are projected as somewhat lower priority problems since with careful planning and relatively simple treatment methods, it is believed feasible to collect and disinfect domestic wastes adequately under postattack conditions. The probable low level of preparedness of the urban population for improvisation still would demand close attention from local health department personnel, however, to assure safe sewage disposal under expected emergency conditions. [Ref. 102].

VIII. HEALTH

A. SURVIVING FACILITIES AND PERSONNEL

Figure 46 illustrates the number of doctors, by county, after relocation. The numerical estimates were arrived at by taking the current number of doctors per county and assuming that the doctors relocated according to the same algorithm as the general population. Thus, the average density of doctors would be the same following relocation and following attack as it is now. Figure 47 depicts the number of people per hospital bed after relocation.

B. INJURIES FROM BLAST AND FIRE

Fatality estimates were made under the assumption that significant medical care was not available and that most survivors injured by blast and fire would have injuries of such a magnitude that they could survive subject only to available first aid and nonprofessional attention. In any case, because of the relocation, the great majority of the population would be out of range of nuclear blast and fire effects. From Figures 7 and 8, and from the assumption that the mean casualty overpressure is 2 psi [Refs 9, 10], the estimated number of people injured by blast/fire from the postulated attack is about 6 percent.

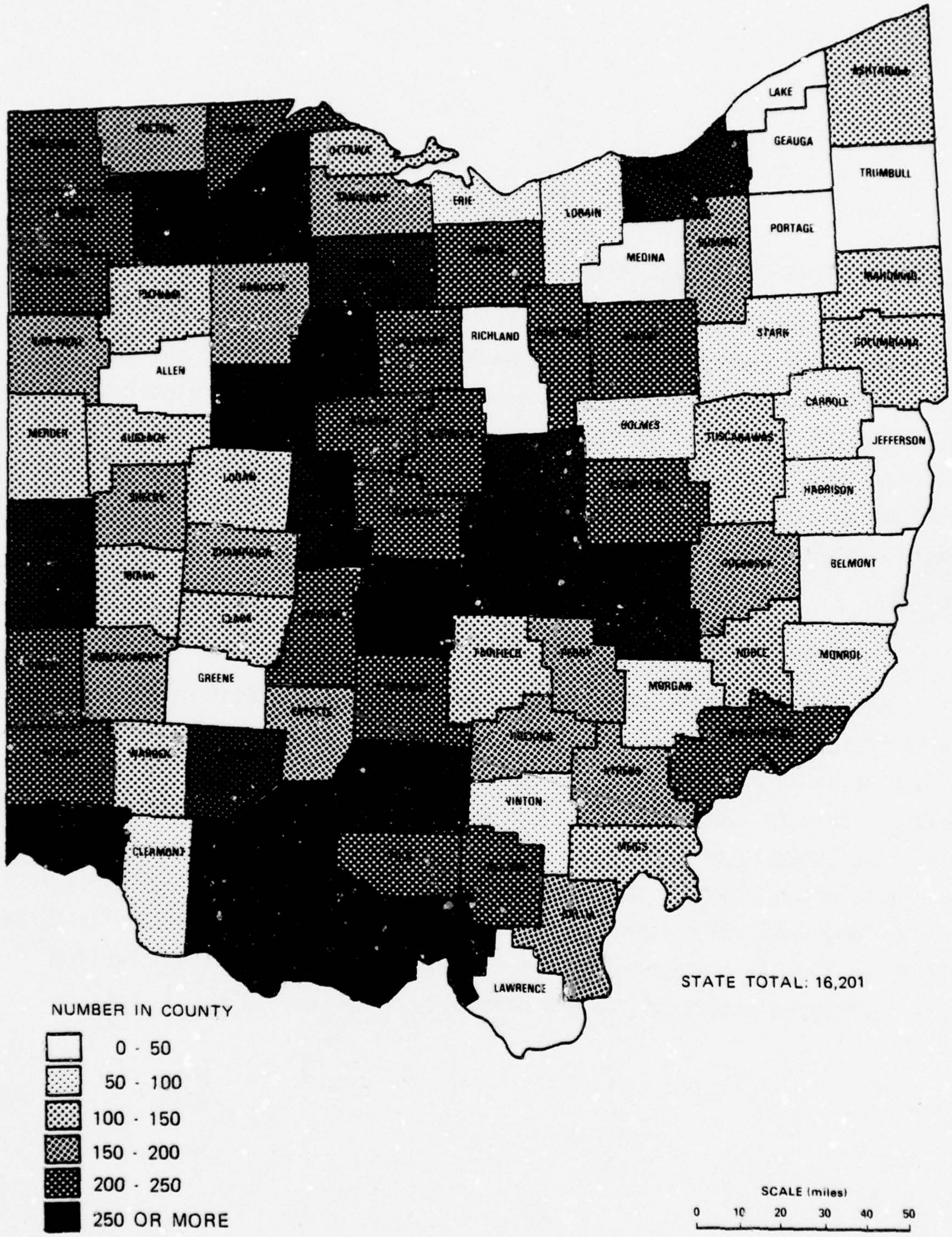


FIGURE 46. DOCTORS IN OHIO AFTER RELOCATION

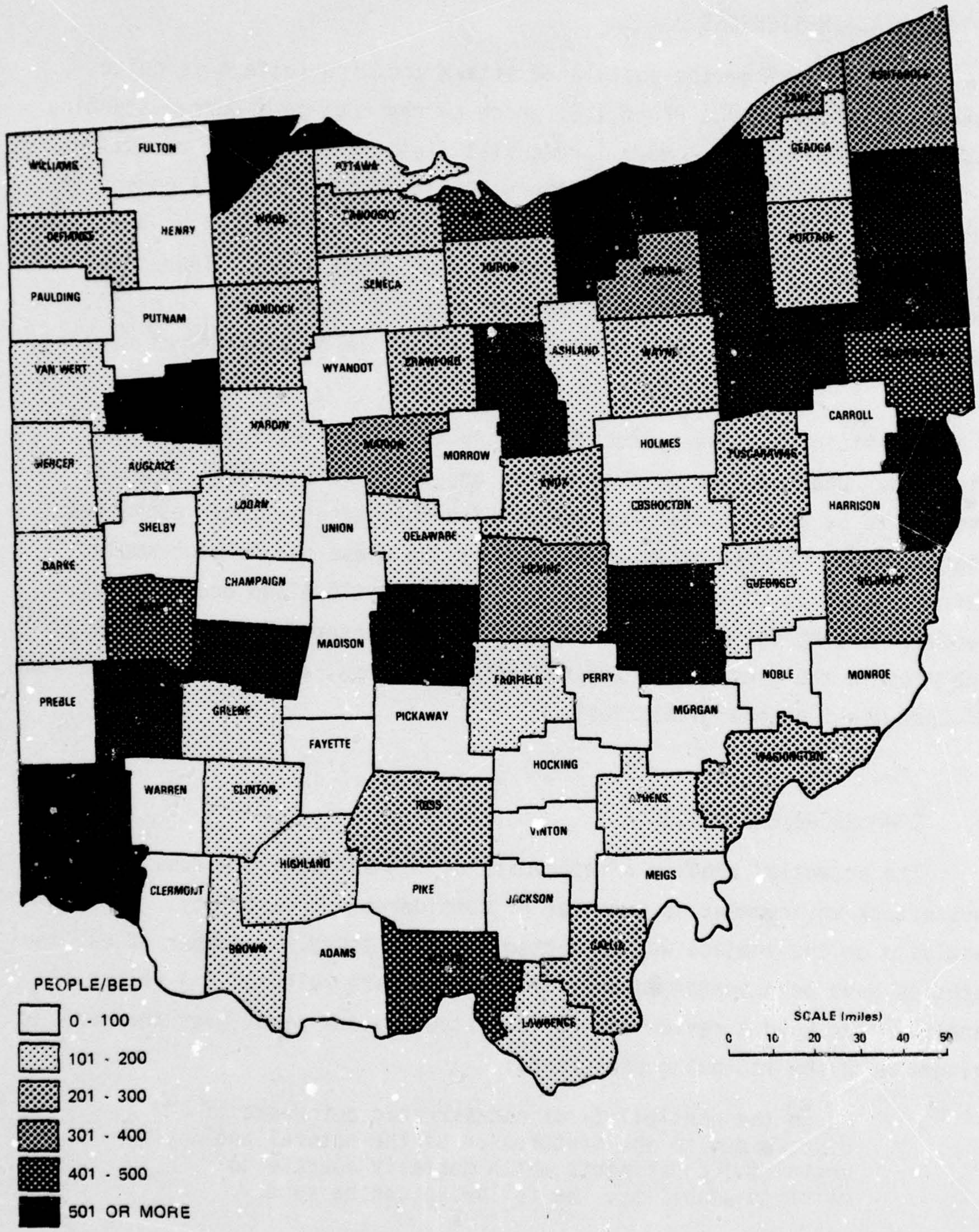


FIGURE 47. PEOPLE PER HOSPITAL BED IN OHIO, AFTER RELOCATION

C. RADIATION SICKNESS

The fallout from the postulated attack and wind pattern is quite intense in Ohio. For a PF of 1.0, which corresponds to a person standing alone in the middle of a very large, flat field, the two-week radiation dose would be at least 2,000 roentgens (R) in most of Ohio. A person in the upper story space of a normal house (PF ~5) would receive at least 400 R, thereby definitely becoming ill and possibly dying. Therefore, fallout protection is essential throughout the state. For a PF of 50, 2,000 R is reduced to 40 R, which has a negligible probability of causing illness.

Maximizing fallout protection is crucial to minimizing radiation sickness. Under the postulated attack and civil defense (all evaucees assumed to be at PF 50 for two weeks, PF 3 thereafter), it is estimated that 10 to 15 percent of the survivors of the blast and fallout would suffer radiation sickness, mostly in areas near Cleveland and Columbus. Because many of the blast-injured people (~6 percent of total population) are also in the group suffering radiation sickness, a substantial fraction of them might become fatalities.

D. COMMUNICABLE DISEASES

The potential problem of epidemics of communicable diseases in the postattack environment is a matter of considerable uncertainty. No new analysis on the subject was conducted for this study. A number of earlier studies have been performed and their results are relevant. A recent analysis included a review of previous studies; the study overview concluded with the following paragraphs:

> As to the possibility of catastrophic outbreaks of disease due to the disturbance of the natural and artificial constraints which normally operate to maintain stability, the following can be said.
>
> The major constraints against epidemics are:
>
> (i) Widespread public awareness and practice of the fundamental principles of sanitation

(ii) Advanced diagnostic techniques permitting early identification of potential threats, which, in turn, makes it possible to mobilize resources where they can be used most effectively

(iii) Artificial barriers such as vaccination, sewage treatment, water sterilization, government monitoring of commercial food processing, deliberate suppression of disease vectors (i.e., mosquitoes, rats, etc.)

(iv) Medical countermeasures: hospitals, antibiotics, etc.

(v) Natural physiological resistance.

It is obvious that in the aftermath of nuclear attack all of these constraints (including the last) would be degraded to some extent. On the other hand, in no circumstances would external conditions seem likely to approach those characteristics of great historical epidemics such as the black plague. Even if every hospital and antibiotic were destroyed, the basic habits of sanitation and knowledge of the dynamics of epidemic disease would still exist. Moreover, one legacy of the preattack period would be a residue of acquired immunity (via vaccinations) or absence of major sources of infection. The one major caveat is that we cannot compare the natural physiological resistance of a postattack 20th-century population with any previous one. The combined death rate from infectious diseases could conceivably be an order of magnitude greater than it is today, while almost certainly remaining very much lower than the average for the Middle Ages, and probably lower than for World War I. [Ref. 103].

Some earlier studies reached the following conclusions:

The modern chemotherapeutic and chemoprophylactic agents as well as BCG vaccine, if made available in the postattack environment, make tuberculosis control a reasonable goal if accompanied by an adequate public health program. Planning is essential if this goal is to be attained.

In the absence of active control, tuberculosis could well be the most serious infectious disease problem in the postattack environment. The infectious agent will undoubtedly be widely disseminated in the survivors of a nuclear attack, and almost all the changes

> brought about in the physical and socio-economic environment can be expected to increase the tuberculosis threat. [Ref. 105, p. vi; Emphasis added].

> Our knowledge of the disease [plague] and its epidemiology, along with modern methods of control and treatment, makes it highly unlikely that an epidemic, such as the "Black Death," will take place even in the disordered environment of a postattack situation. However, this possibility cannot be ruled out entirely if one wishes to assume a sufficiently serious breakdown of organized society as we know it today. [Ref. 106, p. v].

The above studies apparently are all concerned with a nonrelocated population. Although no detailed study appears to have been done of the relative danger of disease in a relocated as opposed to nonrelocated population, it would appear that the lower population densities and lack of blast effects among most of a relocated population would make communicable disease somewhat less of a problem than for a nonrelocated population.

IX. COMMUNICATIONS AND EMERGENCY SERVICES

Although communications and emergency services (e.g., police, fire) are not an absolute necessity in themselves, they are included in this study because they are necessary for coordination of postattack activities, which would be almost essential.

A. COMMUNICATIONS

Figure 48 depicts a schematic map of the Direction and Control network Ohio might establish as a result of upgrading U.S. civil defense to a full Crisis Relocation Plan [Ref. 107]. Emergency Operating Centers (EOCs), established in peacetime, would serve as headquarters for local and state governments in the postattack environment and possess means of communicating with each other. The EOC network is deliberately set up to avoid the major urban areas, which would presumably be destroyed in a large-scale attack. (For further details, see Ref. 108).

Figures 49, 50, and 51 illustrate the current number of AM radio stations,[1] FM radio transmitters, and television transmitters in Ohio. Under the assumption that 2 psi will destroy a transmitter, it is estimated that approximately 60 AM radio stations, 75 FM radio transmitters, and 4 television transmitters would survive. Some of these currently possess emergency generators and fuel supplies, and more would be prepared in this fashion as part of the CRP and during the crisis period. Furthermore, Program D-Prime calls for protecting host-area broadcast stations against Electromagnetic Pulse (EMP) [Ref. 10]. With respect to receiving

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[1]Data on AM transmitters, as opposed to stations, were not available. It is assumed that transmitters and stations are essentially colocated.

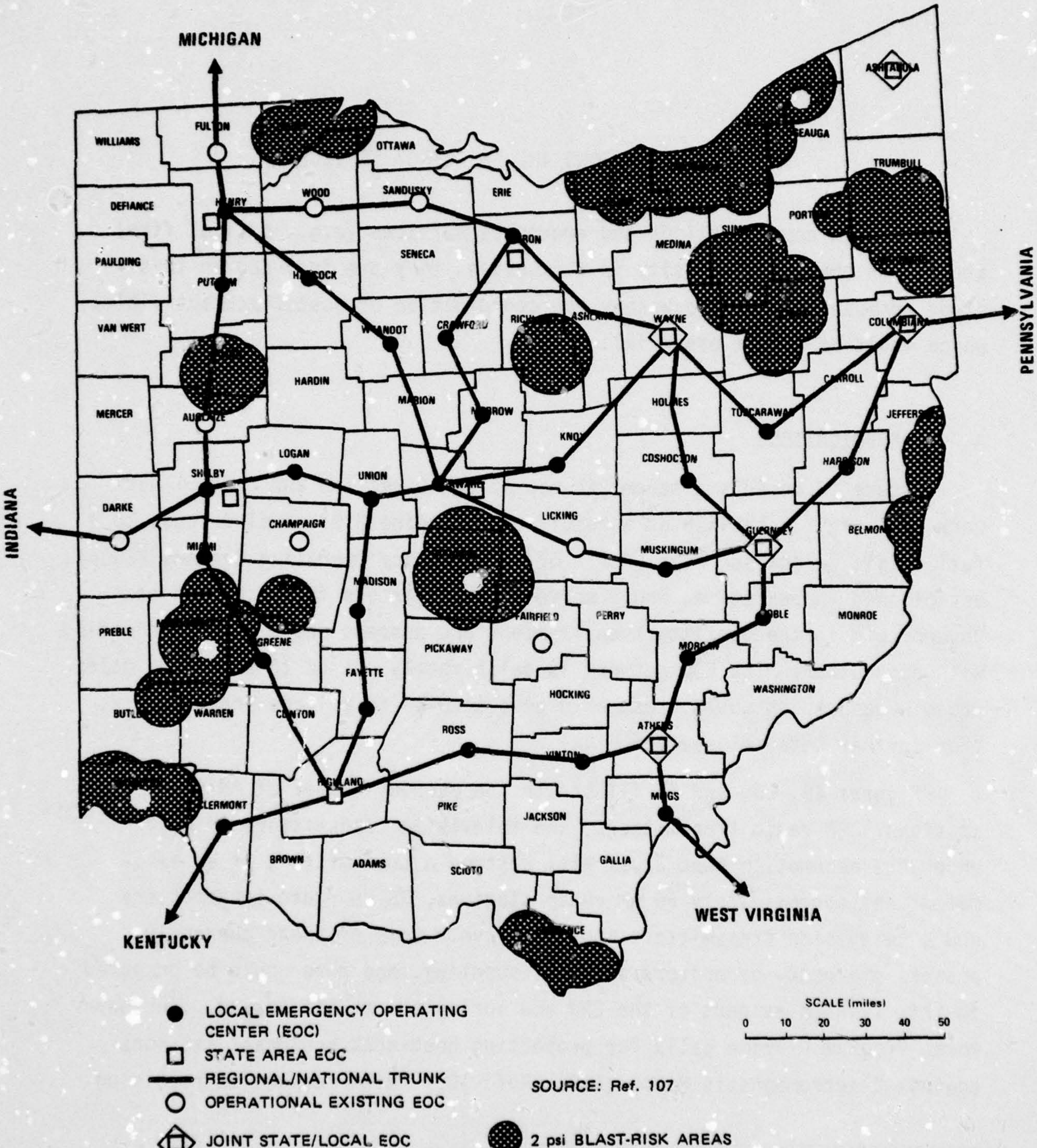


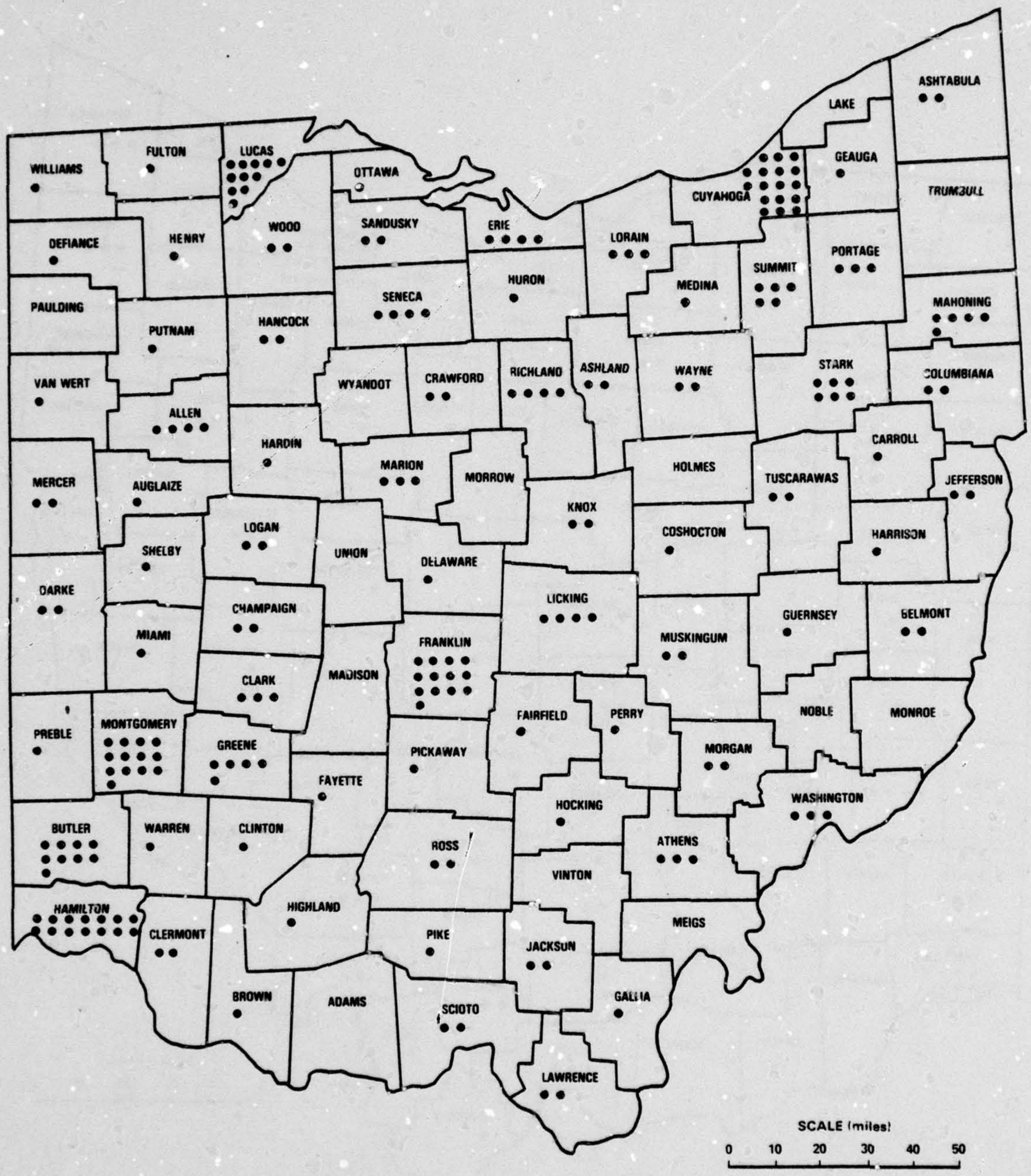
FIGURE 48. SCHEMATIC OF OHIO DIRECTION-AND-CONTROL GRID WITH REGIONAL/NATIONAL TRUNK

TOTAL NUMBER: 134

SOURCE: Ref. 124

*DOTS REPRESENT NUMBER OF STATIONS IN EACH COUNTY, NOT THEIR EXACT LOCATIONS.

FIGURE 49. OHIO AM RADIO STATIONS

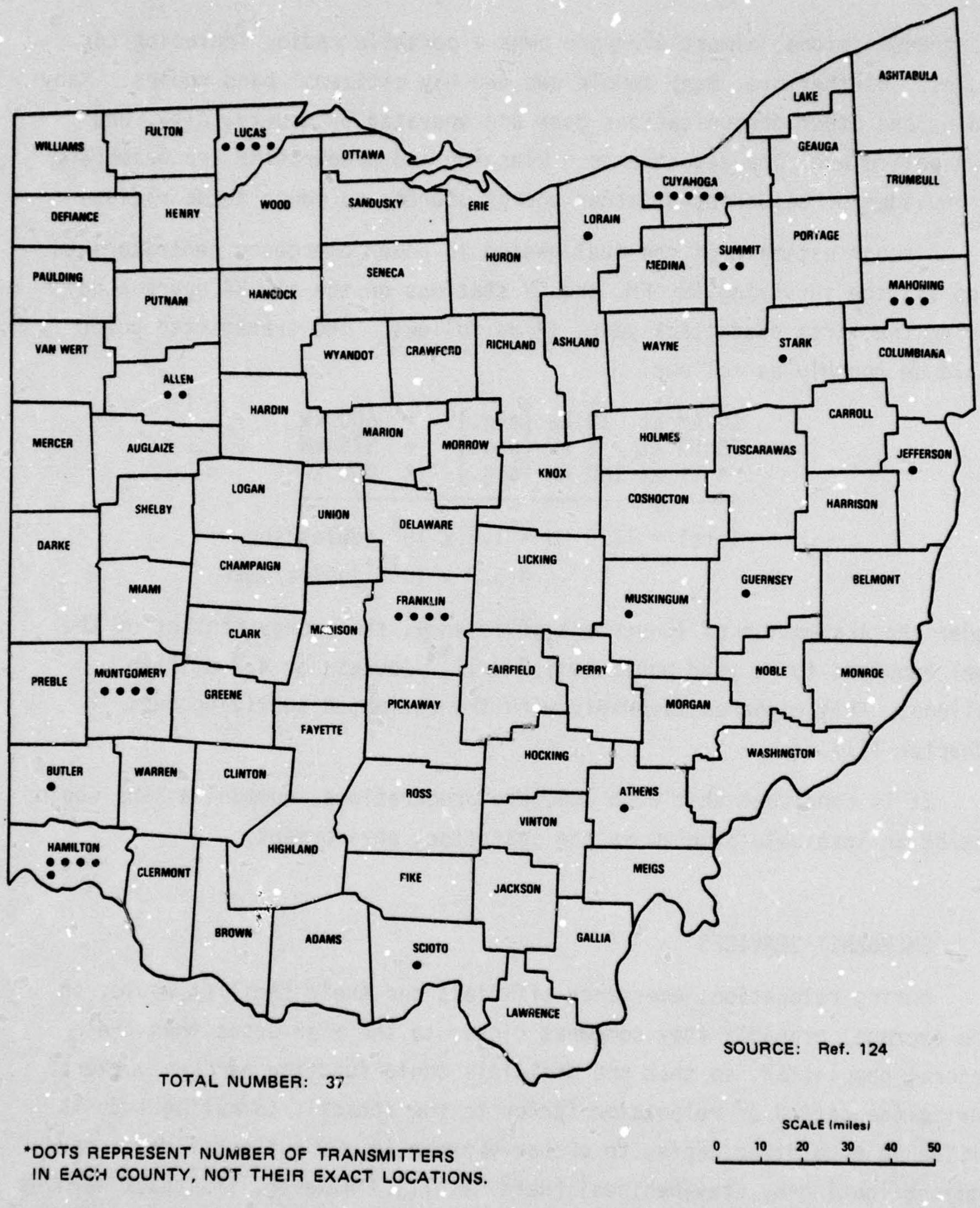


SOURCE: Ref. 124

TOTAL NUMBER: 213

*DOTS REPRESENT NUMBER OF TRANSMITTERS IN EACH COUNTY, NOT THEIR EXACT LOCATIONS.

FIGURE 50. OHIO FM RADIO TRANSMITTERS



*DOTS REPRESENT NUMBER OF TRANSMITTERS
IN EACH COUNTY, NOT THEIR EXACT LOCATIONS.

FIGURE 51. OHIO TELEVISION TRANSMITTERS

the transmissions, almost everyone owns a portable radio, including car radios. Furthermore, many people own two-way citizens' band radios. Many radios and other communications gear are operated by county, city, and town police and fire departments. Planning and preparation are necessary to provide for batteries or other energy sources to power these radios.

A rough estimate of the fuel needed to power emergency generators to keep all the surviving AM, FM, and TV stations on the air 24 hours a day, during the first postattack year, is as follows. The transmitted power would be roughly as follows:

60 AM at 10 kW (avg.)	=	600 kW
75 FM at 5 kW (avg.)	=	375 kW
4 TV at 200 kW (avg.)	=	800 kW

$$\text{Total} = 1775 \text{ kW} = 1.8 \times 10^6 \text{ joules/sec}$$
$$= 5.7 \times 10^{13} \text{ joules/year}$$

Under the assumption of 10-percent efficiency, the energy content of the fuel required for a year would be 5.7×10^{14} joules, or 4.3 million gallons. This compares favorably with the estimated surviving fuel (Chapter III).

It is concluded that with adequate preparations, communications would not be an insoluble problem in the postattack environment.

B. EMERGENCY SERVICES

During relocation, emergency officials and their families would, on the average, probably stay somewhat closer to the risk areas than the general population, so that the officials could function as "key workers" during the period of relocation (prior to the attack), commuting into the cities on a rotating basis, to preserve order (e.g., put out fires, guard against looting by stay-behinds) [Refs. 9, 11]. However, if attack warning (15 to 30 min) came, many emergency officials might still get out of target areas at high speed in their emergency vehicles (most of the general public would already have left).

Following the in-shelter period, it is estimated that the distribution of policemen and firemen would be analogous to that for the public. Figures 52 and 53 illustrate the estimated number of policemen and firemen in Ohio (by county) after the in-shelter period. In preparing these maps, current numbers of policemen and firemen were used as a basis; then these officials were assumed to be relocated according to the same method used by the general population.

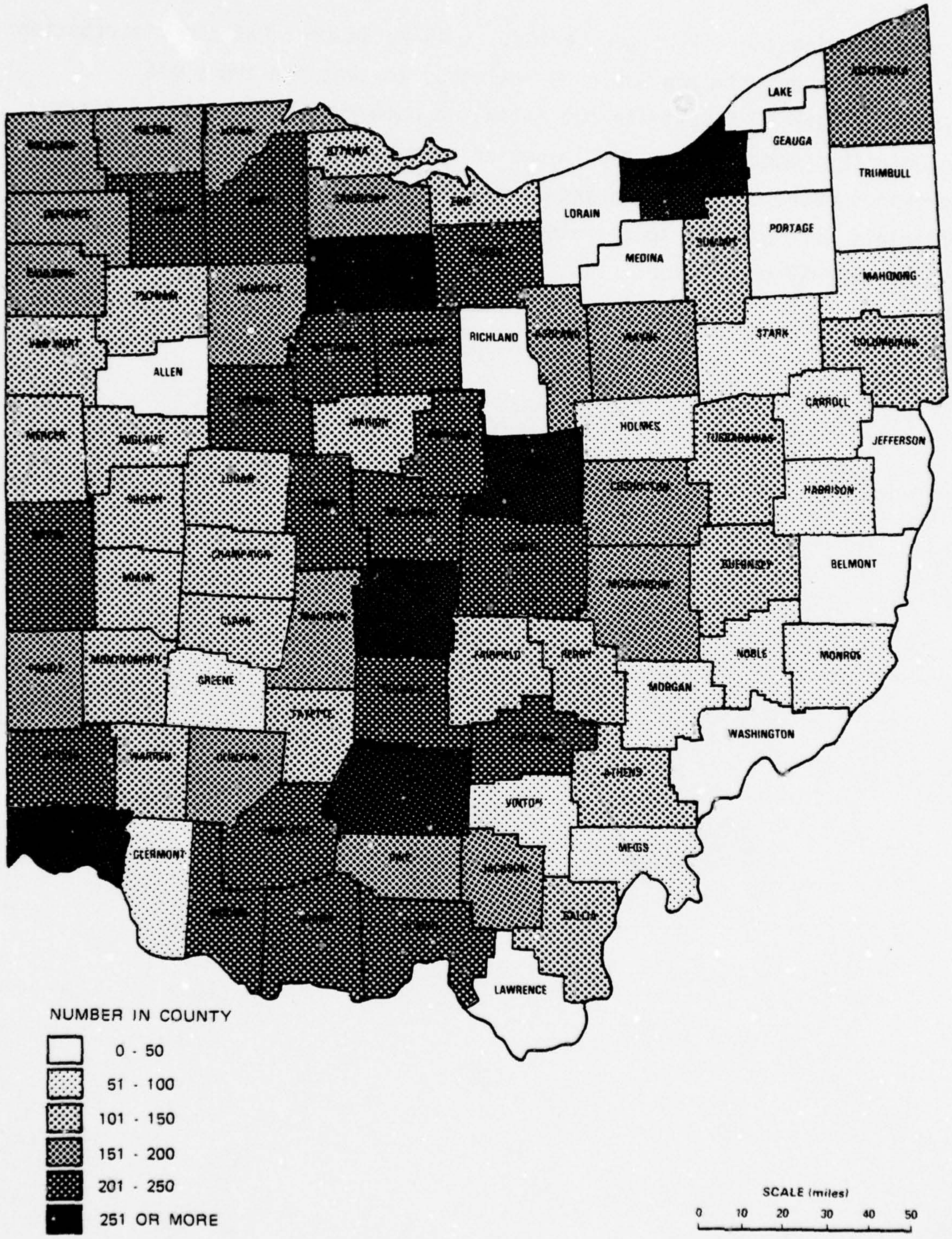


FIGURE 52. POLICE IN OHIO AFTER RELOCATION

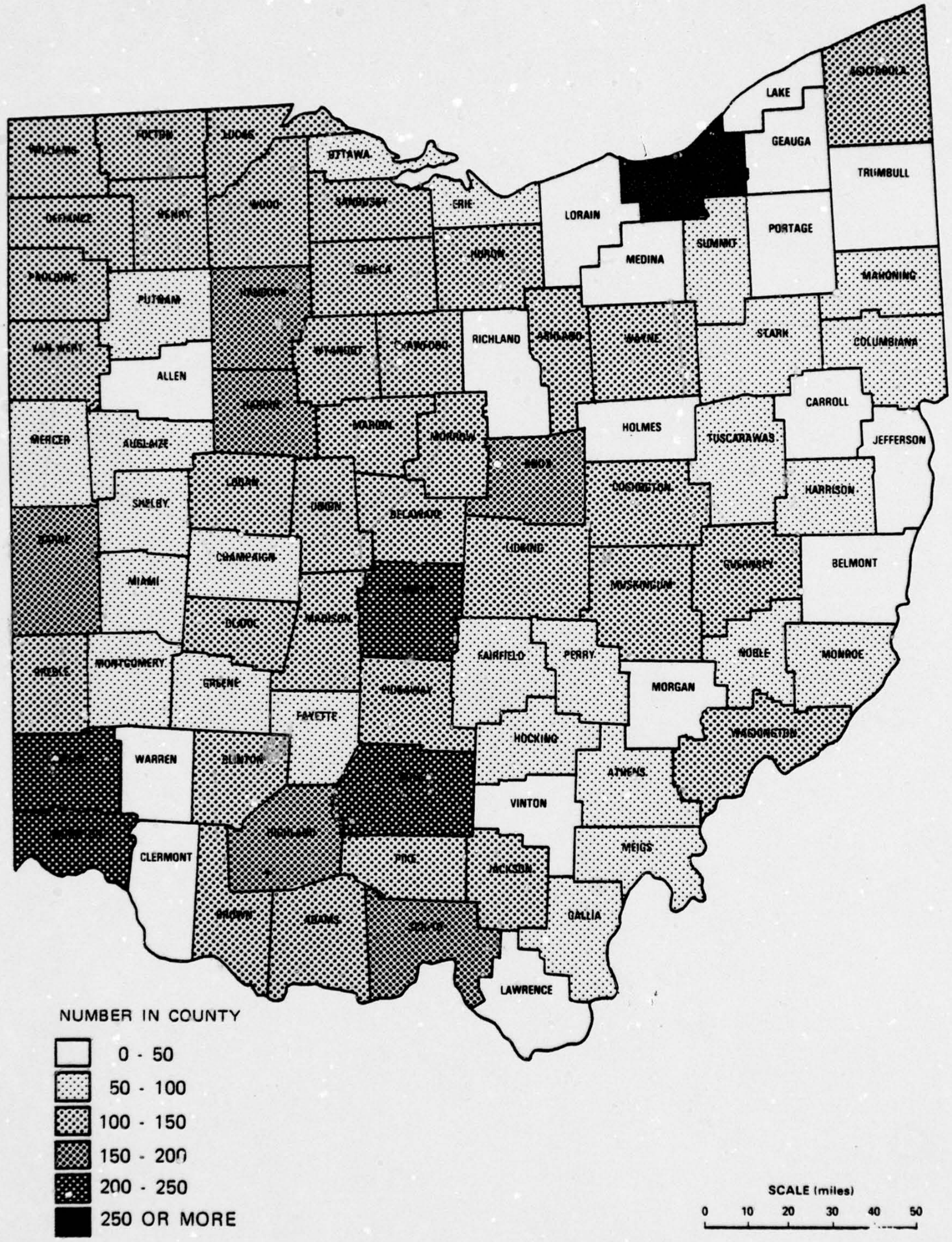


FIGURE 53. FIREMEN IN OHIO AFTER RELOCATION

X. RESIDUAL RADIATION

A. INTRODUCTION

After the fallout radiation from the postulated attack decays below the levels intense enough to have a high probability of causing fatality or illness, the radiation levels will still remain considerably above normal background levels for many months. Some authors [e.g., Ref. 109] have suggested that this residual radiation could cause significant numbers of additional fatalities. On the other hand, an earlier study by System Planning Corporation [Ref. 110] found that the relative level of such additional fatalities would be small for limited attacks against the U.S. involving strikes against only strategic military targets. This result should be more generally applicable because, although the area covered by high-intensity fallout is less for such limited attacks than for large-scale attacks such as the one postulated in this study, the relative intensity distributions of fallout are comparable.

The present analysis is based on reports on the Biological Effects of Ionizing Radiation (BEIR). The first of these [Ref. 111] was published in 1972 and is henceforth referred to as BEIR-72. A revised report (summary only) was issued in 1979 [Ref. 112]. This report includes results of the studies by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). The relevant portions of the 1975 study by the National Academy of Sciences [Ref. 113], which concluded that long-term worldwide effects from residual radiation would be low, were based on BEIR-72 and UNSCEAR. The 1976 SPC study of limited attacks [Ref. 110] was based primarily on BEIR-72.

Effects of radiation on humans may be divided into two types: somatic and genetic. Somatic effects are those that affect the people receiving the radiation. Genetic effects are those that affect the offspring or descendants of the people receiving the radiation.

B. SOMATIC EFFECTS

BEIR-79 concludes the following about somatic effects.

> Evidence indicates that cancers arising in a variety of organs and tissues are the principal late somatic effects of radiation exposure (p. 2). Solid tumors are now known to be of greater significance than leukemia, with respect to excess risk of cancer from whole-body exposure to radiation. Major sites are the breast in women, the lung, the thyroid, and the digestive system. Quantitatively, cancers at these sites now dominate the total cancer risk. These cancers have long latent periods and continue to appear 30 yr or more after radiation exposure (p. 236).

> With few exceptions, the somatic effects considered manifest themselves only years or decades after irradiation and are indistinguishable from lesions that occur naturally in nonirradiated populations. The Subcommittee considers cancer induction to be the most important of these effects. At low doses the radiation induction of cancer is detectable only in a statistical sense; that is, in any given individual a particular effect cannot be attributed exclusively to radiation, as opposed to some other cause. In general, the smaller the dose of radiation, the less the likelihood that radiation was the principal cause (p. 234).

> Reductions in dose rate may decrease the observed radiation effect per unit dose, particularly for low-LET[1] radiation. There appear to be mechanisms, however,

---

[1]LET is "linear energy transfer." Low-LET is radiation characteristic of X-rays and gamma rays. High-LET is radiation characteristic of protons, neutrons, and alpha particles. The fallout radiation considered here is gamma radiation; i.e., low-LET.

> especially pertaining to exposure to high-LET radiation, that increase the observed effect per unit dose when the dose rate is reduced. The Committee recognizes the risk estimates for cancer induction, but believes that available information from human data is insufficient to permit appropriate corrections (p. 4).
>
> It seems probable that, for most types of radiogenic cancer, linear extrapolation from incidence at high doses results in an overestimate of risk associated with doses of a few rads of low-LET radiation. Nevertheless, in most cases the linear hypothesis emerges by default as the simple model whose use appears to be least objectionable in the absence of clear evidence as to the shape of the dose-effect curve (p. 243).
>
> For exposure to low-LET radiation at low doses, most cancer risk estimates based on the linear hypothesis are high and should not be regarded as more than upper limits of risk (pp. 2-3).
>
> In terms of the lifetime excess fatal cancer induced by *low-dose, low-LET radiation, the risk estimate is in* the range of 70 to 353 excess cases per million persons exposed per rad for single exposure, and 68 to 293 per million per rad [per year] for continuous exposure (p. 246).
>
> The conclusions concerning somatic risks have added to and extended the earlier estimates, but in general the present Committee's conclusions are not in fundamental disagreement with those presented in the 1972 report (p. 8).

BEIR-72 considered only continuous doses of radiation, not single doses. The report points out that normal incidence of cancer fatalities in 1967, for the U.S. population of 197.8 million, was 14,336 leukemias and 296,647 other cancers, for a total of 1,572 per million (pp. 172-173). The estimated number of additional cancer fatalities resulting from a continuous exposure of 0.1 rem/year ranged from 1,726 to 9,078; i.e., from 8.7 per million to 45.9 per million (p.169).

Cancer probably accounts for 80 to 100 percent of the late (i.e., after the first few months) fatalities [Ref. 110]. Therefore, only fatalities from cancer are considered here. Figure 54 summarizes the BEIR estimates of the incidence of late fatalities versus radiation dose. BEIR-79 concludes that one-tenth the risk of a single exposure of 10 rads is comparable to the risk of 1 rad/year (p. 342) and that linear extrapolation is "least objectionable" (p. 243). Accordingly, the abscissa of Figure 54 is given in both rads (single exposure) and rads/year (continuous exposure), and a line is provided for easy linear extrapolation. Both the BEIR-79 and BEIR-72 results are plotted and are quite consistent. For comparison, the prompt fatality distribution is also plotted.

It would appear that, within the uncertainties, one may combine the prompt fatality distribution with that for low-dose fatalities to form a single probability distribution for fatalities as a function of dose. In other words, the cancer data may simply represent the "tail" of the distribution for prompt fatalities. To the extent that this is so, the late fatalities from residual radiation have already been taken into account in the fatality estimates made in Chapter II.

Another view of the situation is as follows. Given the postulated attack, a typical 2-week accumulated dose in Ohio for PF 1, for areas where most people survive, is 2,000 to 4,000 R. With the assumed PF 50, this becomes 40 to 80 R. From Figure 54, the fraction of late cancer fatalities would be about 0.01. Given the uncertainties, this could be as high as 0.03. According to the linear extrapolation shown, a single exposure heavy enough to cause an additional 10 percent fatalities from cancer would be about 600 rads.

The conclusion is that, for the postulated attack and civil defense, of the people who survive the fallout radiation during the first few weeks after the attack, a few percent or less will die from late radiation-produced effects.

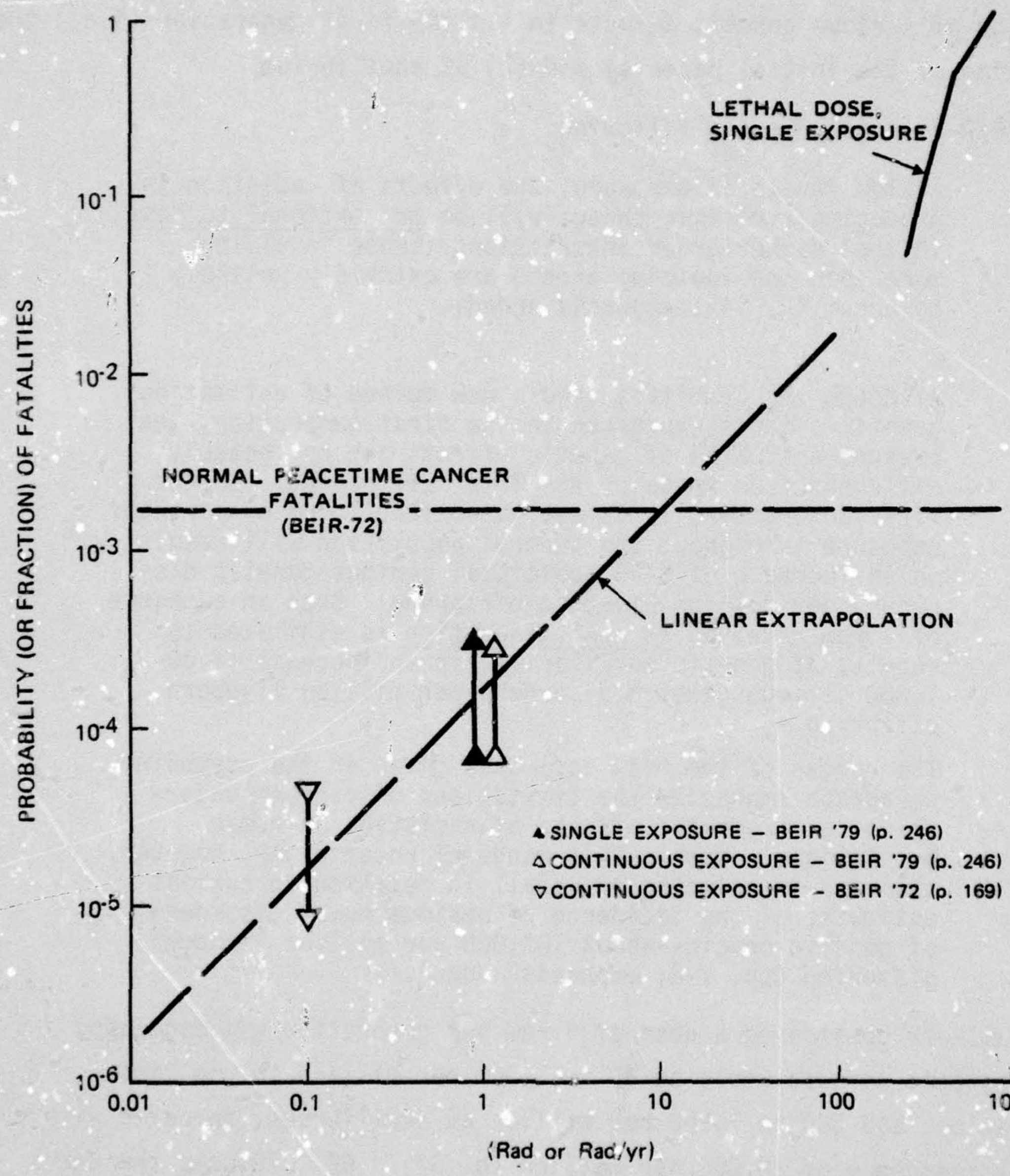


FIGURE 54. LATE FATALITIES (Virtually all are due to cancers)

C. GENETIC EFFECTS

Both BEIR-79 and BEIR-72 consider only the case for which each generation receives comparable radiation. Results are given for the fraction of serious genetic defects in (1) the first generation (i.e., the offspring of the initial parents) and (2) at equilibrium.

BEIR-79 concludes the following:

> At low levels of exposure, the effects of radiation in producing...genetic change will be proportional to dose, in that higher-order interactions (those involving more than one ionizing event) are extremely unlikely to occur (P. 147; emphasis added).

> Although the Committee used a new method of estimating genetic effects expressed in the first generation, the present estimates of genetic effects are not notably different from those of the 1972 BEIR report. In the first generation, it is estimated that 1 rem of parental exposure throughout the general population will result in an increase of 5-75 additional serious genetic disorders per million liveborn offspring. Such an exposure of 1 rem received in each generation is estimated to result, at genetic equilibrium, in an increase of 60-1,000 serious genetic disorders per million liveborn offspring.
>
> The ranges of the risk estimates given in the preceding paragraph emphasize the limitations of current understanding of genetic effects of radiation on human populations. Within this range of uncertainty, however, the risk is nevertheless small in relation to current estimates of the incidence of serious human disorders of genetic origin--about 107,000 per million liveborn offspring (pp. 7-8; emphasis added).

BEIR-72 considered a dose of 5 rem per generation and concluded that genetic defects would be 60 to 1,000 per million in the first generation, and 300 to 7,500 per million at equilibrium, compared with a normal incidence of 60,000 per million (p. 57). BEIR-72 used the terms "genetic damage" and "genetic diseases," not "serious genetic disorders" as in BEIR-79; the definitions may have been slightly different.

Figure 55 summarizes the BEIR data. Both BEIR reports assumed a continuous dose over all generations. The present report is concerned with the case in which the parents receive a radiation dose, but the descendants do not. Such effects are presumably comparable to the "first generation" BEIR estimates. The linear extrapolation shown in Figure 55 reflects this assumption, plus the fact that the BEIR-79 results are more up to date and reliable.

In order to reach a level of disorders equal to the current incidence (10 percent!), the parents would have to receive a dose of about 3,000 rem, almost ten times the dose (450 rem) which produces 50-percent fatalities! If the parents received 450 rem, the incidence of serious genetic disorders would be about 1 percent, or one-tenth of normal. Thus serious genetic disorders caused by radiation from the postulated attack are expected to involve roughly 1 percent (or less) of births, and thus be considerably below normal incidence.

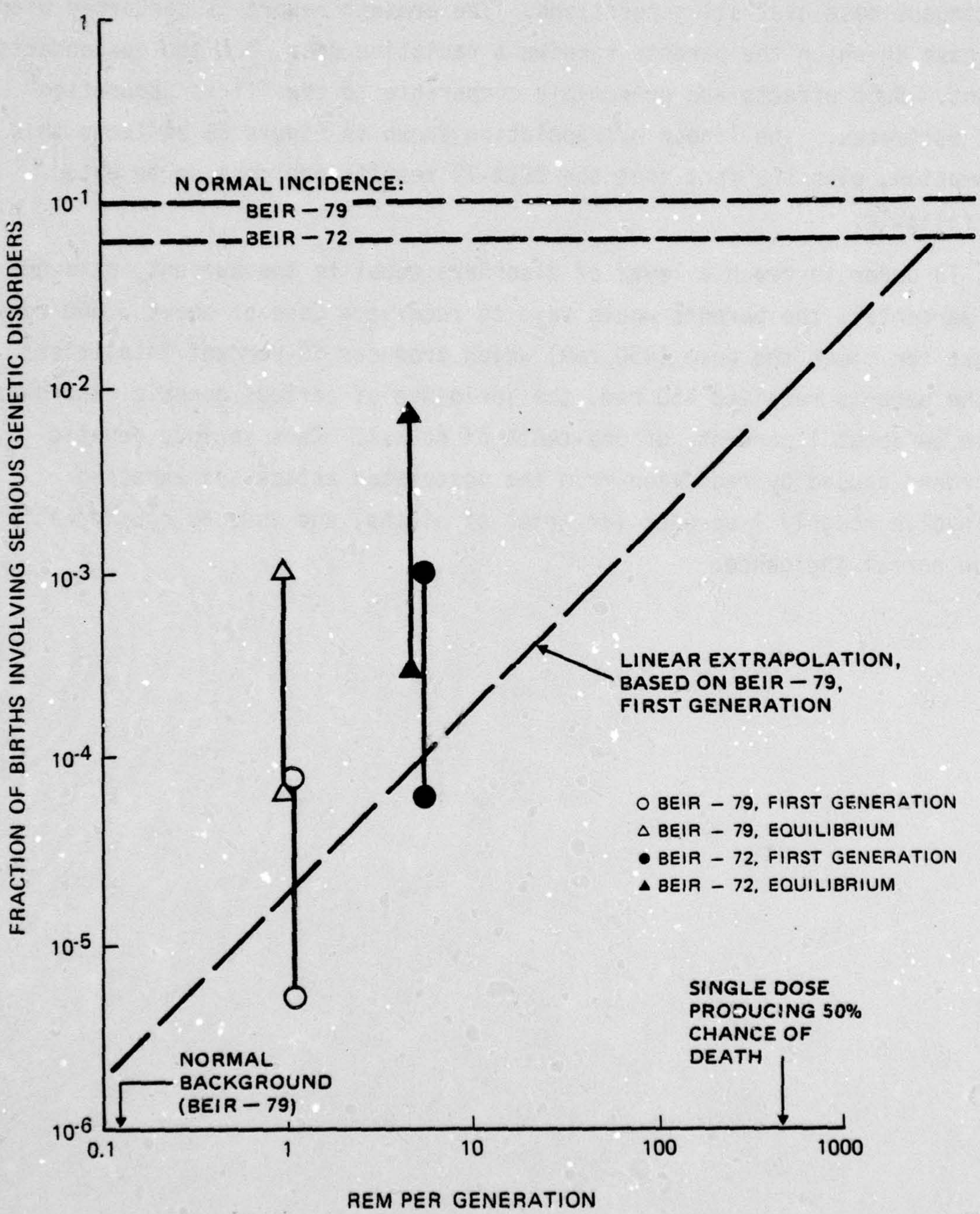


FIGURE 55. SERIOUS GENETIC DISORDERS

XI. ENVIRONMENTAL EFFECTS

A. OZONE DESTRUCTION

1. Summary of Estimates

It has been suggested that the oxides of nitrogen produced in nuclear explosions can be raised to stratospheric altitudes in sufficiently large quantity to cause significant depletion of the earth's natural ozone layer through chemical interactions. Some of the literature on this topic is discussed in Reference 113, pp. 25ff. Reference 113 suggests that, for temperate latitudes in the northern hemisphere after a major U.S./U.S.S.R. nuclear exchange, there would be a 30 to 70 percent ozone depletion for an attack on the order of 10^4 MT, which would correspond to an increase of as much as a factor of 6.5 in the amount of biologically active ultraviolet radiation (UV-B) that reaches the earth's surface [Ref. 113, pp. 42, 72]. This effect would build up over a period of several months, would be most serious for about a year, and then would gradually disappear over a period of 5 years or so.

More recent calculations [Ref. 114] indicate that the degree and duration of ozone depletion are, in most cases, smaller than is suggested in Reference 113 and depend on the weapon yield. For an attack involving 10^4 MT of 4-MT weapons, Reference 114 suggests that the peak ozone depletion would be about 60 percent, corresponding to an increase in UV-B of about a factor of 4; but that the ozone would return to within 15 percent of normal in about 3 years (instead of 5). For a 10^4-MT attack with 1-MT weapons, the maximum ozone depletion is estimated to be 35 percent, returning to within 15 percent of normal in 1-1/2 years. For weapons of 0.35 MT, a small (3 percent) increase in the total ozone is predicted, lasting about 1 year.

It should be noted that the calculations that have been made to date are for air bursts. In this situation, the amount of oxides of nitrogen produced per megaton is independent of detonation altitude, and the proportion that gets into the stratosphere also appears to be independent of height of burst. For surface bursts, however, a rule of thumb is that half the burst energy is used up in vaporizing surface materials. Since only half the bomb energy is then left for production of nitrogen oxides, only half as much of these would be produced. By definition, this assumes that half as much air is heated to the same temperature. If the same amount of air were heated to a lower temperature, even less of the nitrogen oxides would be created.

The validity and conservatism of these estimates is discussed in the next section. A summary of the pertinent facts and uncertainties regarding the depletion of ozone in a major nuclear attack is given in Reference 115 and updated in Reference 116. While many of the uncertainties suggest that the calculations to date considerably overestimate the magnitude of the potential ozone problem, it is important to recognize that large effects are at least possible. It would therefore be prudent to examine potential countermeasures that can be taken in advance to mitigate the impact of increased UV-B radiation on human life after a large nuclear attack.

2. Uncertainties

The uncertainties with regard to ozone depletion are large. There is a factor of 3 uncertainty in the amount of nitrogen oxides produced in a nuclear explosion, at least a factor of 3 uncertainty in the fraction of that material that reaches the stratosphere, and a factor of 2 uncertainty in the total stratospheric burden of those oxides. More comprehensive discussions of the uncertainties in the calculations may be found in References 117 and 118.

Other uncertainties relate to the models used for the estimates. These models all use a perturbation approach, a technique that is entirely inappropriate for a situation in which the amount of material injected is comparable to the amount already there. For the real atmosphere, the

changes associated with the very large injection of nitrogen oxides would lead to major changes in the temperature profile (and hence in the reaction rates) and in the dynamics of the stratosphere. Both effects are significant. Also, a one-dimensional model, such as that of Reference 113, does not take into account the real-life horizontal spreading of the nitrogen oxides. All of these factors suggest that the current models overpredict the amount and, especially, the duration of the ozone depletion from a large nuclear attack.

It should also be recognized that it is not clear precisely what other effects (exacerbating or ameliorating) would occur at various levels in the atmosphere that may influence the amount of UV-B reaching the earth's surface in the event of a major increase in the amounts of nitrogen oxides in the atmosphere.

There are a great many other uncertainties in the physics and chemistry of the stratosphere that are not likely to be resolved in the near future. The stratosphere is extremely complex, and major fluctuations in composition occur in both space and time. Not only are some of the reaction rates uncertain, but not all the significant reactions may actually be recognized and included in the model. For example, the major differences between the older and the more recent calculations are due largely to the inclusion of two ozone-producing reactions previously omitted [Ref. 114]. In addition, the difficulties associated with the acquisition of reliable experimental data on reaction rates and other atmospheric parameters are massive, with the result that input data uncertainties of an order of magnitude are as much the rule as the exception. There are also considerable uncertainties in the stratospheric residence times of various species and their seasonal variations, even for injections that can legitimately be treated as perturbations. The exchange of species between stratosphere and troposphere is relatively rapid in mid-winter and relatively low throughout the rest of the year. It is therefore not possible, either now or in the foreseeable future, to assess the validity of alternative models. Experimental data from injections of nitrogen oxides produced in atmospheric

nuclear explosions have not produced ozone depletions that can be distinguished from natural fluctuations [Ref. 118]. Further, no ozone depletion was observed in 1961-1962, during which the detonation of 300 MT could, in principle, have produced a marginally measurable depletion of the ozone layer [Refs. 115 and 118]. Perhaps the timing of the 200 megatons of Soviet nuclear testing could have reduced the effect, because of both the relatively less intense photochemistry and the rapid downward transport of material from the stratosphere in winter.

3. Adverse Impacts

A 70-percent reduction in the ozone column would mean that, at temperate latitudes, a person would acquire a severe sunburn if exposed to the summer noontime sun for about 10 minutes [Ref. 113]. A 50-percent ozone column reduction would increase the exposure time to about 1 hour. In either case, such exposures would preclude significant out-of-doors activities without some form of protection. The potential for eye damage would also be serious.

For animals, there would be problems of damage to the eyes and exposed skin. Animal problems would be more severe than human problems, because of the limited opportunity for domestic animals to find shelter.

Some domesticated plants might not be able to survive the higher UV doses, although they do better when the amount of visible light is also high. Further, there may be significant interactions of UV radiation with agricultural chemicals. Since many wild species can be expected to have sensitivities comparable to those of domestic plants, some impacts can be expected on ecosystems, such as forests and meadows from ozone depletion [Ref. 113]. However, relatively little is known about the impact of increased UV radiation either on trees or on entire ecosystems. In the case of forests, some mitigation of the effects may occur because of the protection provided by the taller trees and upper branches to lower-lying plants and limbs.

4. Countermeasures

Because the possibility of a large increase in the amount of UV-B radiation reaching the earth's surface after a major nuclear exchange cannot be ruled out, the question naturally arises of what, if any, steps can be taken in advance to mitigate the impact of such an eventuality on U.S. postattack recovery, particularly during the first year postattack. For direct protection of humans, one can stockpile protective eye glasses, protective creams and ointments, and perhaps protective clothing. Associated with such an approach could be stockpiling of educational materials and UV-B measurement instruments for local use, training of personnel to administer the recovery programs, and some additional research on the effectiveness of protective substances, and devices. It is possible that conducting farming at night would present a viable alternative; in any event, shifting working hours to dusk and dawn periods during the summer may be feasible.

Animal protection is much more difficult. The emphasis here would have to be on finding or building shelters for the animals. The latter may prove feasible in areas where unsheltered animals have survived the fallout attack, as several months would be available, of course, if the attack were to take place between June and February, delaying the coincidence between summer and high UV-B radiation. Further, the requirements for animal shelter following the attack would be significantly smaller than normal U.S. requirements because of the reduction of the animal population due to the attack. (Note: For the postulated attack, in Ohio, virtually all unsheltered farm animals would be killed by fallout.)

Possible countermeasures against UV damage to food crops include the development and stockpiling of more resistant plant seeds. Corn, soybeans, and barley, for example, are far more resistant than such species as tomatoes, peas, and onions [Ref. 113, p. 93] and could form the nucleus of a preparedness stockpile. In addition, a search could be made for varieties of these and other important domestic crops that can accept considerably increased UV-B radiation.

A search for UV-resistant agricultural chemicals should be made, with stockpiling as appropriate. Since many insects are relatively resistant to both UV and nuclear radiation, the question of appropriate pesticides may be particularly important.

A summary of the potential ozone problem is given in Table 25.

TABLE 25. SUMMARY OF POTENTIAL OZONE PROBLEM

Anticipated ozone depletion :	0 to 60 percent, depending on weapon yields
Corresponding increase in UV-B:	Approximately factor of 4 (maximum)
Resource	Maximum Impact
Corn, soybeans	Very small
Peas, onions	Large
Wildlands	Uncertain
Farm animals	Moderate
Wildlife	Moderate if cover is unavailable
Humans	Minor with modest avoidance

B. CLIMATIC CHANGE

An overall decrease in average worldwide surface temperatures of "at most, a 0.5°C deviation from the average" has been estimated for a nuclear attack on the order of 10^4 MT [Ref. 113, p. 57]. This effect, due to the dust raised to stratospheric altitudes by the nuclear explosion, would build up over a period of months and would decay over a period of a few years.

Such an effect would be minor compared to at least one historical event. In 1815, Mt. Tambora, in the Dutch East Indies (now Indonesia) violently errupted, spewing about 25 cubic miles of debris into the atmosphere. Worldwide temperatures were abnormally low for the next year, giving rise to "the year without a summer." In 1816, in New England, it snowed in June, and killing frosts continued through August; the mean

temperature in June, 1916, was about 3°C below normal [Ref. 119]. For a nuclear attack to produce this much dust would require about 500,000 megatons, surface burst. Thus, the climatic effects of the postulated attack would apparently be negligible by comparison.[1]

C. OTHER EFFECTS

A number of other widespread ecological effects have been mentioned as possibly occurring in the U.S. after a nuclear attack; e.g., mass fires, loss of forests, and widespread soil erosion. Although uncertainty dominates such possibilities, analysts so far appear not to have assigned them high probability.

[1]No quantitative estimates appear to exist regarding attenuation of UV-B by dust following an attack, but such attenuation would almost surely be negligible.

XII. SYNTHESIS

A. FUEL: SUMMARY OF POSTATTACK USE

As has been mentioned a number of times throughout this report, if electric power were generally unavailable after an attack, petroleum fuel would be highly desirable for performing a number of critical functions. A summary of rough estimates of fuel requirements for these critical functions is as follows.

- Minimum Transportation of Food

  Food (grain) to be transported
  = 8.8 million survivors
  x 1/3 without adequate local food
  x 2,500 Cal/day/person
  x 365 days/year
  ÷ 3.5 million Cal/ton [Ref. 120; 1 ton = 2,000 lb]
  = 0.77 million tons

  Average round-trip distance: ~300 miles

  Fuel required:

  by truck (50 ton-miles/gallon) = 4.6 million gallons
  by rail (190 ton-miles/gallon) = 1.2 million gallons.

- Transportation of Coal

  Coal required for electric power generation
  = 31 million megawatt-hours surviving annual capacity
  x 3.6 x 10^9 joules/megawatt-hour
  ÷ 2.7 x 10^{10} joules/ton of coal [Ref. 121, p. 7-2]
  ÷ 0.4 conversion efficiency [Ref. 121, p. 9-84]
  = 10.3 million tons

  Average round-trip distance: ~300 miles

  Fuel required:

  by truck (50 ton-miles/gallon) = 62 million gallons
  by rail (190 ton-miles/gallon) = 16 million gallons.

- **Mechanized Farming** (See Chapter V-c)

  Fuel required
  = corn: 22.0 gal/acre x 3.8 x 10^6 acres
  + wheat: 9.6 gal/acre x 1.6 x 10^6 acres
  + soybeans: 19.0 gal/acre x 3.1 x 10^6 acres
  = 160 million gallons.

- **Pumping of Ground Water**

  Water required
  = 8.8 million survivors
  x 5 gallons water/day
  x 3.77 kilograms/gallon
  x 365 days/year
  = 6.1 x 10^{10} kilograms

  Energy required
  = 6.1 10^{10} kilograms
  x 30 meters typical depth
  x 9.8 meters/sec^2 (gravity)
  ÷ 0.1 pump efficiency
  = 1.8 x 10^{14} joules

  Energy content of fuel = 1.3 x 10^8 joules/gallon

  Required fuel = 1.4 million gallons.

- **Radio/TV Stations**

  Surviving transmitter capacity
  ≅ 1,775 kilowatts
  = 5.7 x 10^{13} joules/year

  Fuel required = 5.7 x 10^{13} joules
  ÷ 0.1 efficiency
  ÷ 1.3 x 10^8 joules/gallon
  = 4.4 million gallons.

- **Emergency Vehicles**

  Fuel required = 64,000 surviving emergency vehicles (80 percent)
  x 5,000(?) miles/year (conserving fuel)
  ÷ 15 miles/gallon
  = 20 million gallons.

The total of these estimates is as follows:

Purpose	Millions of gallons/year
Transporting food (minimum)	1.2-4.6
Transporting coal	16-62
Mechanized farming	160
Pumping ground water (if no electric power)	1.4
Radio/TV stations (if no electric power)	4.4
Emergency vehicles	20 (?)
Total	200-250

However, per Chapter III, the estimated surviving fuel is ~190 million gallons. It appears that although fuel supplies surviving the postulated attack would be sufficient for emergency needs other than agriculture, they might not be sufficient for mechanized agriculture unless extensive fuel conservation were employed. Thus, extensive manual agriculture might be necessary.

B. SUMMARY OF RESULTS

A brief summary of the findings of the previous sections of the report is as follows, assuming the postulated attack and civil defense, and making the stringent assumption that Ohio is isolated for a year.

- Energy: Coal production facilities would survive. Several coal-burning electric power plants would survive. Petroleum refinery capability would be destroyed. Surviving petroleum fuel would probably be adequate for transportation of essential goods and other emergency functions, but possibly not for full mechanized farming, and definitely not for use of private automobiles.
- Transportation: Most cars, trucks, and trains, plus an extensive network of roads and tracks, would survive.

- Food: Most farm animals would be killed by fallout. People would have to shift to a much more grain-oriented diet. Whether surviving stored food would be adequate to feed the surviving population for a year would depend on the season of the attack. The next crop following the attack could probably be mostly saved, although it might be destroyed by heavy fallout and/or bad weather during the in-shelter period. Effects of these uncertainties could be removed by stockpiling grain in rural areas.
- Water: Postattack water supplies would apparently be adequate.
- Housing: Until rebuilding occurred, people would have to live at 2 to 4 times current densities, but this is still feasible.
- Clothing: Preattack clothing would largely survive and could be used for several years after the attack.
- Sanitation: Waste disposal would be primitive for some sections of population, but again, this is feasible.
- Health: Fatalities from disease would increase, possibly by an order of magnitude over the normal peacetime rate, but not to levels comparable to the fatalities from the initial blast and fallout.
- Communications: Many radio and TV stations would survive. A small fraction of total surviving fuel supplies could power them for well over a year.
- Emergency Services: Surviving emergency officials and vehicles per capita would be comparable to preattack levels.
- Residual Radiation: Late fatalities from residual radiation would be a few percent, or less, of the people surviving the initial blast and fallout.
- Environmental Effects: Depletion of the ozone layer, and consequent increase in ultraviolet radiation, might occur. However, severe damage to people would be unlikely. Staple crops (especially corn) would probably not be significantly damaged. Other significant environmental effects appear unlikely.

C. DISCUSSION OF RESULTS

The aforementioned results were obtained under three basic assumptions:

- The 6,500-megaton attack is directed against military facilities, industrial facilities, and population centers, but not evacuees per se; 77 percent of yield is surface burst.
- The civil defense includes crisis relocation and expedient fallout protection in the host areas.
- Ohio is isolated for a year.

The second assumption is, of course, necessary for survival of a majority of the people. The third assumption was made for ease of analysis; the real case ought to be more favorable.

Regarding the first assumption, a real attack could produce either more harmful or less harmful conditions. On the one hand, despite the Soviets' writings and statements, they might, in fact, deliberately target evacuees. On the other hand, an attack such as the postulated attack might well be carried out with many air-bursts, particularly against fairly soft, urban targets; the 5-psi damage radius for a given yield is considerably less for a surface burst than for an air burst, which would produce negligible fallout. Although not a full "worst-case" attack, the postulated attack seems to be "bad enough" to use as a basis for an analysis of the postattack situation.

With respect to transportation, water, housing, clothing, sanitation, communications, and emergency services, surviving facilities appear adequate to support the surviving population during the first year after the postulated attack, and to provide a reasonable expectation for continued support thereafter. Furthermore, fatalities from disease, residual radiation, and environmental disturbance (especially ozone-layer depletion) would be small compared to the initial fatalities from blast and fallout.

Surviving fuel would be adequate, during the first year, for emergency needs other than mechanized agriculture; but the latter might not be fully available, thus making some manual agriculture necessary. A countermeasure would be stockpiling of adequate fuel.

The only phenomenon identified by this study that could pose a serious threat to the continued survival of the people who survived the initial blast and fallout, is destruction of crops following the attack. This might occur in the event that (1) the attack occurred in summer or early fall and heavy fallout destroyed the entire crop, or (2) the attack occurred just prior to harvest time, and bad weather combined with fallout to destroy the crops while the people remained in shelters. Even so, this result reflects the stringent assumption that Ohio is isolated. It is hard to

believe that such crop destruction could happen nationwide. In any case, the obvious countermeasure is stockpiling a year's supply of grain.

Thus the primary threat to population from a nuclear attack would be the initial blast and fallout. If most people relocate away from risk areas, then the only serious threat to their survival, from the postulated attack, is the fallout, because of its deleterious effects on people, animals, and plants--primarily crops. Most animals probably cannot be saved, but they are not essential for human survival. Whether crops would be killed depends on the details; stockpiling grain would greatly alleviate the impact of this uncertainty. The most important countermeasure to fallout is, of course, the expedient fallout protection adopted by the evacuees in the host areas. All evacuees should be instructed to achieve as high a PF as possible, and stay in shelters until told that it is safe to come out.

In addition to analyzing the issue of whether people could survive during the first year after a nuclear attack, the present study has also sought to achieve some insight into the issue of whether the survivors could, in principle, establish a stable, self-sustaining society that would appear to have a good chance of surviving indefinitely. Although this issue was not analyzed quantitatively, it does appear very relevant that many societies, past and present, exist or have existed for many generations under conditions, which, in many ways, are considerably more primitive than the conditions that would probably exist in Ohio following the postulated attack. On this basis, it is concluded that the survivors would stand a good chance of possessing enough resources and capability to achieve a stable, self-sustaining society, which could lead eventually to recovery.

D. COUNTERMEASURES

This section contains a general discussion of preventive measures that could be carried out in peacetime. Some are included in Program D-Prime as it is currently conceived, and some are not. Section E describes Program D-Prime and the preventive measures that it would imply.

There are several elements of an effective relocation plan that are essential to its success. These include instructions for expedient shelter construction, explicit instructions for evacuees and recipient areas, and an attack warning system. Other necessary preattack arrangements include provisions for some form of government and monetary system, topics that lie generally beyond the scope of this report.

The probability of successful survival during the first year and later (and the rapidity of postattack recovery as well) will also depend on the comprehensiveness and effectiveness of other preattack measures that can serve to ameliorate some of the more severe postattack conditions. Appropriate preattack preparations, coupled with extensive dissemination of understandable instructions for postattack activities, can vastly improve the lot of the survivors.

1. Measures of General Applicability

The limited supplies of essential resources must last until new supplies (especially food and fuel) can be made available. These supplies are necessary both for ensuring first-year survival and for setting the stage for subsequent societal recovery. It will therefore be essential to have established a regional resource allocation scheme that can be administered and enforced locally. This implies that:

- Local allocation authority must be established in advance of the relocation, along with a chain of command to regional, if not federal, authority.
- Local allocation plans must be available.
- Some form of military or police force must be prearranged.
- Resource locations must be known.
- Flexibility to adapt to unanticipated conditions must be provided for.

The flexibility indicated in the last bullet is required if the authority is to establish and maintain credibility; the flexibility must be limited in order that local special interests not distort excessively the survival and recovery process.

A second necessary measure for large-scale survival in a postattack environment is the availability of well-designed survival handbooks--informative, understandable, and possibly tailored to the season during which the crisis relocation occurs. The content of the handbooks should include, inter alia, instructions on avoiding unnecessary radiation exposure, preparing food grain for consumption, conserving resources, building simple tools, obtaining necessary supplies, and acquiring authoritative information. The handbook should be stored in nontarget areas. If separate handbooks are prepared for the different seasons, precise dates should be established in advance to determine which handbooks are issued.

Storage of material intended to facilitate postattack survival should be accomplished in a more or less decentralized manner, away from anticipated target areas. This suggests that, in the crisis period, normal movements of goods should be drastically altered. Nonessential deliveries should be halted, and shipments of such essentials as food and fuel should be redirected to build up stocks in nontarget areas (subject to the constraints, of course, of minimal interference with the relocation of the population). To the extent possible, useful equipment (including railway engines, cranes, and fuel trucks) should be moved out of the target areas as well.

Because of the anticipated difficult postattack conditions, it would appear desirable to concentrate authority and resources in local allocation, distribution, and information centers.

2. Measures Appropriate to Specific Concerns

a. Energy

It is anticipated that the reconstruction of central utility facilities will take a considerable period of time for the attack considered (and several years, at a minimum, if power plants are targeted). For this reason, it will be essential to make effective use of those energy resources that survive.

One important measure is to ensure that fuel stored underground can be made available. While it is likely that human ingenuity will find a way of tapping these supplies effectively, it would be useful to arrange that many of the pumps be modified to permit easy conversion to manual operation. A second measure might be to store, perhaps underground, the essential equipment for rebuilding small refineries. Third, one should ensure that existing natural gas supplies can be exploited.[1] Fourth, in view of the potential importance of such battery-operated devices as mining lights in coal-producing areas, battery-operated radios and calculators nationwide, and other battery-powered devices, it may prove desirable to provide centralized battery storage and battery-charging facilities at the resource allocation offices. Fifth, some consideration may be given to utilizing the nation's refineries and transportation system in a surge mode during the crisis period to produce fuels, and especially to transport fuels from risk to host areas. Finally, it may be useful to arrange local storage of maps of electric power grids, gas and oil pipelines, and fuel storage facilities for the use of the postattack allocation authorities.

b. Transportation

Stockpiling of bicycle parts (particularly tires and wheels) and hand pumps in the local areas could be useful to provide personnel and

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[1]Small natural gas wells exist on many farms in Ohio (and presumably elsewhere). While extensive utilization may not be economic under peacetime circumstances, such resources may be significant in a postattack environment. This topic requires further investigation on a local basis.

goods transport. Also, one should stockpile, outside target areas, the necessary equipment for repair of railroads.

c. Food

Food is the area of greatest concern for first-year survival, particularly if the attack should occur just before the corn harvest. Clearly, some kind of a rationing system will be required at least from the time of relocation until the following year's harvest. This rationing system must ensure, insofar as possible, that people will have enough food to permit them to perform their tasks and, at the same time, that the food supply will last until the new harvest. While the rationing system will have to operate locally (at least at first), the possibility of food transfers to other communities, presumably in return for other necessities, must be kept in mind at the local level.

Since the vast majority of the food supplies in Ohio (and presumably elsewhere) will be in the form of unprocessed grains, understandable instructions will have to be available for converting these crops into edible form (as in Ref. 58). Flavorings (salt, spices) may be required (or at least highly desirable) to make them palatable. Local grinding and milling facilities may also prove useful.

With regard to meat, it is clear that the vast majority of the domestic animals in Ohio would not survive the attack considered. The possibility of quickly slaughtering and eating animals which had received high gamma doses should be studied. Furthermore, one should stockpile protein-rich foods, especially dried milk, dried eggs, and edible concentrated protein.

Reconstitution of domestic animal herds after the attack will be a serious problem. If only a few of the animals survive, reconstitution will, of necessity, be primarily from outside the affected area. On the other hand, if, say, 10 percent of the young female animals are sheltered and survive with only small radiation doses, and if a sperm bank has been established, herds can be fully reestablished in a period on the order of

10 years. The first-year cost, in terms of food consumption, would be considerably less than 10 percent of the cost of feeding the entire herd.

Reconstitution of agriculture would be an even more important problem. Not only should seed for the major food crops be stockpiled, but consideration should be given to stockpiling seeds of fast-growing plants that might prove useful if the harvests are interrupted. Development of seeds for UV-resistant plants might be useful in case the ozone depletion problem (Chap. XI) proves to be serious. Consideration should also be given to fertilizer and insecticide stockpiles (or, alternatively, to facilities and raw materials for their production). Whether and to what extent these steps are needed requires further investigation. Some thought also needs to be given to the mode of postattack farming. Should labor and materials be concentrated on large farms for a partially mechanized attempt to produce enough food on a large scale? Or should the emphasis be placed on small individual labor-intensive farming? The answer to this question will affect the seed storage requirements mentioned above.

Instructions for decontamination of foodstuffs are also required, as people may be reluctant to consume even slightly contaminated food so long as they are not actually starving.[1]

In all of these preparations, the influence of attack season must be taken into account. In particular, the steps to be taken in the preattack crisis days may well vary with the season.

d. <u>Water</u>

The extent to which it is desirable or necessary to stockpile potable water depends on the overall water situation. For Ohio, there appears to be little need for such stockpiling (on the average, at least), provided

[1]The tradeoff between ingestion of radiation-contaminated food and starvation is strongly in favor of ignoring the contamination, so much so that the prospect of starvation 6 months ahead should logically outweigh the penalties of eating moderately contaminated food [Ref. 57]. Nonetheless, availability of simple measurement and decontamination procedures would bypass this issue entirely.

that provisions are made for utilizing the ample supplies of groundwater that exist there. In particular, arrangements need to be made to permit manual pumping of groundwater, to instruct the population on simple methods of decontamination, and to provide enough information and directions so that people can dig new wells in appropriate areas. Local groundwater maps should be stored in the allocation centers. Storage of potassium iodide to serve as a dietary supplement for children (to preclude or ameliorate thyroid problems associated with ingestion of radioactivity) should also be undertaken, along with provision for its administration.

e. Housing, Clothing, and Sanitation

Evacuees should be provided instructions on how best to live in the type of rural public buildings to which they will be assigned.

Because people may be in relocation areas throughout at least one cold season without adequate fuel for heating, evacuees should be advised to bring warm clothing and sleeping bags with them, regardless of the season of attack.

Instructions to evacuees should emphasize ways of minimizing health hazards from human waste disposal.

f. Health

Because the precise communicable diseases that may arise cannot be predicted in advance, it would be highly desirable to provide laboratory facilities and appropriate technical personnel for the analysis of disease and the production of appropriate vaccines. The degree of decentralization appropriate to postattack conditions of limited transportation needs to be analyzed.

Another problem that needs considerable thought is the development of rules and criteria for utilization of the limited stocks of drugs, medical facilities, and medical personnel. One option is to use the large supplies of veterinary-grade antibiotics for humans during the first postattack year [Ref. 122].

g. Communications

As indicated above, provisions should be made for recharging batteries for use in radio receivers. In addition, a central area for dissemination of printed information should be set up. For this purpose, an inventory of printing presses (especially those that can be operated without fuel or electricity) and of paper stocks should be maintained locally.

h. Ozone

In addition to the steps mentioned earlier, protective creams, ointments, and eye glasses should be available to ameliorate the effects of the increased UV-B that may result from ozone layer depletion. Furthermore, instruction should be provided for outdoor workers on when it is necessary to avoid sunlight.

E. EFFECT OF PROGRAM D-PRIME

In 1978, the Department of Defense decided to request funding for an enhanced civil defense program. This program, sometimes known as Program D-Prime, would include extensive plans for crisis relocation and construction of expedient fallout protection in host areas. A comparison of the budgets of the current civil defense program and Program D-Prime is given in Table 26.

Program D-Prime is a low-cost civil defense program that is oriented almost entirely toward protecting the public from the effects of blast and fallout. For this, it could be extremely effective. Reference 9 concluded that, if relocation were executed during a serious crisis prior to a large-scale attack, the fraction of survivors in the U.S. would be about 90 percent with D-Prime[1] and only about 30 percent with current civil defense.

[1] Actually Reference 9 evaluated a "Program D." Protection for Program D is the same as for Program D-Prime; only the funding schedules are different.

TABLE 26. COMPARISON OF COSTS OF CURRENT CD AND PROGRAM D-PRIME

	Current CD[a]	Program D-Prime
Shelter		
Survey	10	60
Planning[b]	0	50
Material[b]	0	0
Peacetime Construction	0	0
Marking	0	5
Stocking	0	260
Shelter Management	0	50
Nuclear Protection Planning	46	200
Warning	32	50
Direction and Control	39	325
Radiological Defense	22	90
Emergency Public Information, Training, Education	5	150
Management	300	350
Research and Development	26	80
5-Year Cost	480	1,670
Annual Cost (First 5 Years)	96	335
Annual Cost (Dollars per U.S. Citizen)	$0.45	$1.55

[a]Based on FY 1979 DCPA Appropriation, totalling $96.5 million for FY 1979.

[b]For development of shelters during crisis.

Source: Reference 10.

The present study found that, for a somewhat different large-scale attack, the fraction of survivors for Ohio would be about 80 percent with D-Prime and only about 20 percent with no civil defense.

Despite the fact that D-Prime does not specifically include extensive plans or preparations for survival during the first year after a nuclear attack, there are two program elements of D-Prime under which such plans and preparations could begin: Nuclear Protection Planning ($200 million/year) and Emergency Public Information ($150 million/year). Table 27 summarizes the major recommendations of this report and shows the degrees to which they might be implemented by Program D-Prime.

Instructions to the public regarding key items for evacuees to bring with them to the host areas, and regarding life in the postattack environment could certainly be prepared under D-Prime. Such instructions could, in themselves, prevent many fatalities during the first year after the attack. Furthermore, under D-Prime, key materials for stockpiling could be identified. Some plans for the postattack environment might be made, including plans for stockpiling key materials in peacetime, producing them during a period of tension, and relocating them during an intense crisis. However, detailed preparations for the first postattack year, involving cooperation with state/local government and industry, would appear to require a civil defense program more extensive than D-Prime.

TABLE 27. RELATIONSHIP OF KEY RECOMMENDATIONS TO PROGRAM D-PRIME

Key Recommendations	D-Prime Emergency Public Information	D-Prime Planning	Beyond D-Prime
• Prepare instructions regarding postattack environment	•		
• Advise evacuees to bring key items	•		
• Identify key materials		•	
- Stockpile in peacetime			•
- Plan/prepare[a] for producing extra materials during prolonged international tension		•	•
- Plan/prepare[a] for relocating materials during crisis		•	•
• Plan/prepare[a] for relocating vehicles during crisis		•	•
• Plan/prepare[a] for manual pumping of fuel		•	•
• Plan/prepare[a] for manual pumping of water		•	•
• Plan/prepare[a] for immunizations		•	•

[a]Program D-Prime could provide the "paper plans," but not the detailed preparations.

Appendix

CONVERSION FACTORS

CONVERSION FACTORS

Length: 1 meter = 100 centimeters (cm) = 3.281 feet

1 mile (statute) = 5,280 feet

= 1,609.4 meters

Area: 1 square meter = 10.76 square feet

1 acre = 43,560 square feet

1 hectare = 10,000 square meters

= 2.47 acres

1 square mile = 640 acres

= 259.0 hectares

Volume: 1 cubic meter = 35.3 cubic feet

1 liter = 10^{-3} cubic meters

1 gallon = 3.78 liters

1 barrel (oil) = 42 gallons

Mass/weight: 1 kilogram = 1,000 grams = 2.20 lb

Energy: 1 joule = 1 kilogram-meter-$(\text{second})^{-2}$

= 1 watt-second

1 watt-hour = 3,600 joules

1 megawatt-hour = 3.6×10^{9} joules

1 Calorie (kilogram-calorie)

= 1,000 calories (gram-calories)

= 4,185 joules

1 British Thermal Unit (BTU) = 1,054.8 joules

Energy content of gasoline:

$$20{,}750 \text{ BTU/lb*} \times 1{,}054.8 \text{ joules/BTU}$$
$$\div\ 453.6 \text{ grams/lb}$$
$$\times\ 0.739^{*} \text{ grams/cm}^3$$
$$\times\ 1{,}000 \text{ cm}^3\text{/liter}$$
$$\times\ 3.78 \text{ liter/gallon}$$
$$= 1.35 \times 10^8 \text{ joules/gallon}$$
$$= 126{,}000 \text{ BTU/gallon}$$
$$= 36.9 \text{ kilowatt-hours/gallon.}$$

Radiation [Ref. 123]:

1 roentgen (R) = the amount of x or gamma radiation required to produce, in 1 cm^3 of dry air, 1 esu each of positive and negative ions

1 rad = 100 ergs/gram of absorbed dose

1 rem = 1 rad (for x, gamma, and beta radiation only)

1 rep (roentgen equivalent physical) = the amount of radiation corresponding to the absorption of 93 ergs/gram of soft tissue.

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* Ref. 121, pp. 7-21.

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TABLES (Continued)

FIGURES

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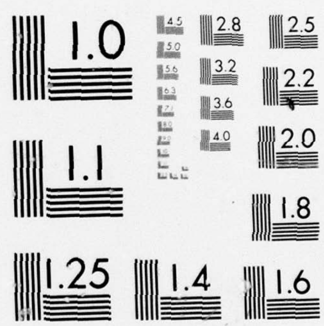

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Abstract

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